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Call for Manuscripts

The editors of the ***NCSM Journal of Mathematics Education Leadership (JMEL)*** are interested in manuscripts!

The editors are particularly interested in manuscripts that bridge research to practice in mathematics education leadership. Manuscripts should be relevant to our members' roles as leaders in mathematics education, and implications of the manuscript for leaders in mathematics education should be significant. At least one author of the manuscript must be a current member of NCSM. Categories for submissions include:

- **Case studies and lessons learned** from mathematics education leadership in schools, districts, states, regions, or provinces
- **Research reports** with implications for mathematics education leaders
- **Professional development** efforts including how these efforts are situated in the larger context of professional development and implications for leadership practice
- Other categories that support the NCSM vision will also be considered.

Submission Procedures

Each manuscript will be reviewed by two volunteer reviewers and a member of the editorial panel. Each manuscript will be reviewed by two volunteer Each manuscript will be reviewed by two volunteer Each manuscript will be reviewed by two volunteer Each manuscript will be reviewed by two volunteer Each manuscript will be reviewed by two volunteer reviewers and a member of the editorial panel. Manuscripts should be emailed to the Journal Editors, currently Drs. Brian Buckhalter and Erin Lehmann, at **ncsmJMEL@mathedleadership.org**.

Submissions should follow the most current edition of APA style and include:

1. A Word file (.docx) with author information (name, title, institution, address, phone, email) and an abstract (maximum of 120 words) followed by the body of the manuscript (maximum of 12,000 words)
2. A blinded Word file (.docx) as above but with author information and all references to authors removed.

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NCSM

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NCSM is happy to announce the 53rd NCSM Annual Conference!

Whether you are a first-timer or a veteran of NCSM annual conferences, join us for three exciting days in Atlanta GA, focused on important issues for leaders in mathematics education.

Take this opportunity to enlarge your network of colleagues who can assist you in building and supporting your local mathematics program and to meet new friends who share your interests and love of mathematics education. Become a part of NCSM, the mathematics leadership organization for educational leaders that provides professional learning opportunities to support and sustain improved student achievement.

Join us in Atlanta, GA, September 20 - 22, where exciting opportunities await you!

For more information and to register for the conference, please see our website:

mathedleadership.org/pl/conference-atlanta-2021

Comments from the Editors

Brian Buckhalter, *Buck Wild About Math, LLC*
Erin Lehmann, *University of South Dakota*

"Leadership is not a license to do less; it is a responsibility to do more." (Sinek, 2014, p. 286).

After a year of teaching during unprecedented times, teachers deserve a huge round of applause. If you have not taken the time to thank a teacher, please do so! Whether in person or virtual, mathematics teachers are engaging in what they do best: meetings the needs of all students. Even during these trying times, we found that teachers would engage in their own professional learning to increase their knowledge and expertise as it looked much different from the year before.

Professional development can and will look different in years to come and as leaders in mathematics education, this is the time to provide these unique and sometimes familiar opportunities to our teachers. This support can come in the form of instructional coaching, asynchronous or synchronous professional development, counseling, and mentoring (Helmke, 2020; NCSM, 2019). In this issue of JMEL, authors provide professional development ideas and suggestions as well as best practices and recommendations to meet the ongoing learning needs of our mathematics teachers.

The first article, "An Interdisciplinary Coaching Approach to Data-Based Individualization: A Year-Long Partnership Between Mathematics Teachers and Special Education Researchers," Mason & Thomas describe a year-long partnership between a group of general education mathematics teachers and their special education researcher-coach counterparts. Findings from this investigation indicate teachers had high rates of satisfaction with the coaching model and that, by some specific measures, this model demonstrates promise for improving teachers' assessment practice within a data-based individualization framework.

Our second article, "Design and Impact of Flexible, Asynchronous Online Video-based Mathematics Professional Development," Seago, Knotts, & Carroll share the experimental research design and preliminary impact results from the Video in the Middle project, which is adapting existing face-to-face video-based mathematics professional development materials to online two-hour modules that can be used in flexible asynchronous formats: independent, locally facilitated, or developer facilitated. The benefits of this asynchronous PD became pronounced as the pandemic emerged during the research study and teachers found themselves shifting to remote instruction with little time to prepare.

In our final article, "Mathematics Curricular Reform in Schools: Secondary Leaders' Perceptions," Bauer, Lehmann, Reed, & Zimmermann explored the nature and extent of transformational leadership practices and efficacy beliefs exhibited by secondary school leaders as they implement a mathematics curricular reform. The research findings suggest efficacy beliefs related to relationships and experience influence leaders' transformational leadership practices as they facilitate curricular reforms in their schools. Furthermore, these transformational leadership practices may be used to address and overcome barriers throughout the implementation of curricular reforms.

We encourage you to engage in reflection as a leader. What went well this school year? What are your next steps for improvement? What type of learning atmosphere are you creating? But more importantly, please take time this summer for some self-care as we know educators put everyone else's needs before their own. ✪

References

Helmke, S. (2020). Address the stress: How leaders can support teachers in an extraordinary year. *Learning Professional, 41*(5), 36-37.

NCSM. (2019). *NCSM essential actions: Instructional leadership in mathematics education.* NCSM.

Sinek, S. (2014). Leaders eat last: Why some teams pull together and others don't. Penguin Group.

Curricular Reform in Schools: Secondary Leaders' Perceptions

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Erin Lehmann, *University of South Dakota*
Kristine Reed, *University of South Dakota*
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Abstract

The landscape of PK–12 education is dynamic, constantly adapting to meet the needs and demands for student learning. These changes inspire curricular reforms, and such processes compound the complexity of leadership roles within PK–12 education settings. This study explored the nature and extent of transformational leadership practices and efficacy beliefs exhibited by secondary school leaders as they implement a mathematics curricular reform. In addition, the study examined the barriers of curricular reform processes as perceived by school leaders. This study employed a phenomenological methodology as participants were asked to describe their lived experiences within the context of the mathematics curricular reform. Semi-structured interviews and focus groups were used for data collection, allowing participants to share stories and examples that captured the essence of their lived experiences. The research findings suggest efficacy beliefs related to relationships and experience influence leaders' transformational leadership practices as they facilitate curricular reforms in their schools. Furthermore, these transformational leadership practices may be used to address and overcome barriers throughout the implementation of curricular reforms.

Introduction

Change is constantly reshaping the landscape of PK–12 education settings as standards, technology, and instructional design adjust to meet the needs and demands for student learning. In response to changing content standards over the past ten years, states across the nation implemented policies demanding greater standardization and accountability measures to monitor student achievement (Hollingworth et al., 2017; Leone et al., 2009; Yongmei et al., 2018). These changes in content, standardization, and accountability also led to shifts in pedagogy and instructional design. Ultimately, these changing demands inspire curricular reforms and consequently compound the complexity of leadership roles in PK–12 education.

While there are numerous studies examining teachers' perceptions with regards to curricular reforms, there is little known about school leaders' beliefs, perceptions, and experiences throughout such change processes (Donohoo, 2018; Dupas, 2016; Flood & Angelle, 2017; Schreiner, 2014). This phenomenological study presented an opportunity to address this gap in the literature and capture the experiences and perceptions of school leaders as they implemented a mathematics curricular reform (Creswell & Poth, 2018; Moustakas, 1994). Within the context of PK–12 schools in this study, leadership roles included principals, assistant principals, deans, and teacher leaders as they influenced instructional and curricular goals throughout the implementation of a curricular reform.

The transformational leadership approach outlines how school leaders may engage teachers, motivating and nurturing them through the curriculum change process (Northouse, 2016). It is through this reciprocal relationship that school leaders encourage growth and development among teachers. Furthermore, the transformational leadership approach requires school leaders to be cognizant of their own beliefs and behaviors in relation to the needs of teachers as they guide curricular change (Northouse, 2016). Bandura (1993) defines this as one's efficacy beliefs, or their personal perceptions regarding their own abilities. These efficacy beliefs influence how leaders may "feel, think, motivate themselves, and behave" within the scope of a curricular reform (Bandura, 1993, p. 118). Although several studies examine the transformational leadership approach in education (Hauserman & Stick, 2013; Leithwood & Sun, 2012; Leone et al., 2009; Pietsch & Tulowitzki, 2017), few, if any, studies explore the interrelationship between efficacy beliefs and transformational leadership practices.

Purpose of the Study

The purpose of this phenomenological study was to inform leadership beliefs and practices of secondary education leaders as they prepare for and implement mathematics reforms in their schools. This study explored the roles and beliefs of secondary school leaders during a mathematics curricular reform, as well as uncovering their perceptions of barriers to the curricular reform process. Transformational leadership provided the theoretical framework for the study, anchoring the research in leadership factors that describe "how leaders can initiate, develop, and carry out significant changes in organizations" (Northouse, 2016, p. 175). Given the qualitative methodology, the purpose was not to examine the success of the curricular reform, rather, this study explored leaders' efficacy beliefs as an integral component of transformational leadership within the context of curricular reform processes.

Research Questions

This study strived to illuminate the role and practice of secondary leaders in guiding curriculum reforms. To gather insight into the role of secondary education leaders during the implementation of a new mathematics curriculum, this study was directed by the following research questions:

1. How do secondary school leaders exhibit transformational leadership practices during a curricular reform?
2. What are the barriers of a curricular reform as perceived by secondary school leaders?
3. How do secondary school leaders' perceived efficacy beliefs influence the nature and extent of their role during a curricular reform?

Theoretical Framework

This phenomenological study was situated within the framework of transformational leadership. Transformational leadership is defined by the relationship between leaders and followers (Northouse, 2016). Bernard M. Bass propelled the idea of transformational leadership by developing a model through which leaders motivate followers to accomplish goals that benefit the group rather than the individual (1985, 2000). The model identified four factors which affect a leader's ability to transform the thinking and actions of followers: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration (Bass, 1985; Northouse, 2016). Kouzes and Posner (2017) further identified the need for leaders to be honest, competent, inspiring, and forward-thinking to drive transformational change. These factors cultivate the relationship between leaders and followers as they approach change within their organization (Kouzes & Posner, 2017; Northouse, 2016).

Central to the transformational leadership approach is both leaders' and followers' self-concepts (Bass, 2000; Northouse, 2016). One's self-concept is influenced by their efficacy beliefs. Bandura (1989, 1993) asserted self-efficacy beliefs are determined through motivational, cognitive, affective, and selection processes. These processes lead individuals to exercise human agency as they set goals and anticipate outcomes (Bandura, 1989). Efficacy beliefs, then, are complementary to the transformational leadership approach when studying the lived experiences of school leaders implementing a curricular reform.

Review of the Literature

Transformational Leadership and Leading Change

Leaders in education are tasked with guiding many forms of complex change, thus requiring them to become transformational change agents that support their school communities in being flexible and adaptable to such changes (Bass, 2000). Transformational leadership operates through the relationship between leaders and followers (Bass, 1997; Kouzes & Posner, 2017; Leithwood & Sun, 2012; Minckler, 2014; Northouse, 2016). Through their leadership practice and behaviors, transformational leaders build connections to engage and motivate followers to work towards organizational goals (Leithwood & Sun, 2012; Minckler, 2014; Northouse, 2016). Thus, Northouse (2016) claims the transformational leadership approach "requires that leaders become social architects" within their organizations (p. 176). Leaders enact transformational approaches as they construct the culture and community of their organization through the relationships they build with and among their followers (Leithwood & Sun, 2012; Minckler, 2014). Within educational settings, transformational leaders shape school culture as they communicate a shared vision, foster collaboration, and build trust (Kouzes & Posner, 2017; Leithwood & Sun, 2012; Minckler, 2014). In addition, one of the key roles of school leaders is to act as a change agent (Leone et al., 2009), motivating growth and transformation as they build the capacity of teachers' instructional practices (Pietsch & Tulowitzki, 2017). Frost and Harris (2003) extend these practices to all leadership roles within the context of school settings, asserting interpersonal skills and relationships ultimately determine the extent to which leaders, including teacher leaders, influence the beliefs and practice of their colleagues.

Shared Leadership

Leithwood (2016) supports a synergistic leadership model that harnesses the power of all leadership roles, claiming this approach is stronger than individual leadership roles or when leadership roles are missing. School organizations are shifting from the typical model of formal leadership authority to a collegial model predicated on teamwork and relationships among both assigned and emergent leadership roles (Harris, 2005; Leithwood, 2016). Connected school leadership establishes coherence within the organization (Brondyk et al., 2015), promoting balanced decision-making processes and interdependence among school leaders and staff (Harris, 2005; Yongmei et al., 2018). These interdependent structures foster trust and leadership beyond assigned roles within the school organization (Flood & Angelle, 2017). Furthermore, leaders that form supportive, connected school systems engage and motivate staff to embrace changes, such as curricular reforms, aligning to the vision and direction of the organization (Bass, 2000; Brondyk et al., 2015; Kezar, 2018; Leithwood et al., 2007).

Efficacy

Bandura (1993) asserts "efficacy beliefs influence how people feel, think, motivate themselves, and behave" (p. 118). He further established the role of efficacy beliefs within learning organizations by developing the constructs of teacher efficacy and collective efficacy (1993). Several researchers emphasize the leader's influence on teacher and collective efficacy beliefs of staff within their school settings (Bandura, 1993; Dupas, 2016; Flood & Angelle, 2017; Goddard & Goddard, 2001; Kitsantas & Ware, 2011; Minckler, 2014).

However, Burns (1978) highlights leadership efficacy, emphasizing the role of the transformational, self-efficacious leader in developing an environment where learning and innovation flourish. Leadership efficacies are described as the knowledge, skills, and abilities of leaders to address and overcome challenges, thus contributing to the leader's effectiveness in creating a culture that inspires others to do the same (Dupas, 2016; Dyson, 2019).

Curricular Reforms

The momentum and excitement of implementing new curricular methods and materials to benefit student achievement can be used to establish a culture that welcomes change and growth in schools (Valencic-Miller, 2017). This culture is largely dependent on how school leaders implement change, and this in turn impacts the transition school staff make in taking ownership of the new initiative (Valencic-Miller, 2017).

ADMINISTRATORS AND CURRICULAR REFORMS

Effective school leaders use their knowledge of the school's culture when planning for and implementing change in their buildings (Hollingworth et al., 2017). Moreover, school administrators recognize the magnitude of change and the degree of disequilibrium the reform may cause among staff members (Miller et al., 2016). Curricular reforms often require adjustments to organizational and instructional paradigms that are deeply rooted in the culture of the school (Miller et al., 2016). For such complex change processes, a balanced and coordinated system of leadership roles and styles are necessary to influence the culture and commitment to change in the school (Pietsch & Tulowitzki, 2017).

One key role of school administrators is that of a change agent, setting the direction for continuous school improvement (Leone et al., 2009). The foundation of this role rests in the administrator's ability to gain the trust of school staff and to empower teachers to grow and embrace change (Hollingworth et al., 2017; Leone et al., 2009;

Schreiner, 2014). Administrators cultivate trust as they allow teachers to have reasonable autonomy through the change process (Hollingworth et al., 2017; Schreiner, 2014), which in turn encourages educators to take risks and be innovative in their teaching practice (Leone et al., 2009). Furthermore, administrators recognize the strengths of staff members and their past accomplishments, utilizing these teachers' expertise to drive the implementation of reforms (Hollingworth et al., 2017; Schreiner, 2014). Reform is a delicate balance for school leaders, but a clear vision and collaborative goals give meaning to the curricular work and contribute to the implementation of the reform (Barnes & Toncheff, 2016; Leone et al., 2009; Rogers, 2003; Schreiner, 2014).

Administrators cite several sources of information and leadership practices that contribute to their ability to implement successful curricular reforms. McIntosh et al. (2016) reports administrators are more supportive of new initiatives after obtaining further knowledge, thus recommending training opportunities for administrators. Once administrative leaders understand the potential benefits of the curricular reform, Glatthorn et al. (2012) and Yoon (2016) suggest leaders use data to influence teacher buy-in. Leaders also report the importance of engaging in explicit and purposeful conversations with teaching staff (Hollingworth et al., 2017), emphasizing the need to be a good listener and valuing teacher voice throughout the change process (Valencic-Miller, 2017). Finally, effective school leaders provide opportunities for staff development, both formal and informal, to support teachers' abilities in utilizing the curriculum (Glatthorn et al., 2012). Staff development is especially critical during the implementation stage of curricular change as this is when the context is built for introducing new methods and materials to improve current courses (Glatthorn et al., 2012).

SECONDARY TEACHERS AND CURRICULAR REFORMS

All teachers can lead change, including curricular reforms, whether from a positional or emergent leadership role (Frost & Harris, 2003). Teacher leaders are commonly defined as those that influence colleagues with regards to content knowledge and instructional pedagogy (Frost & Harris, 2003). An individual's teaching capacity and authority is influenced by their knowledge of the content and instructional practices, their interpersonal skills, and the situational context and culture of the school (Frost & Harris, 2003). In turn, the school's context and culture are shaped by the extent to which administrators support teacher leadership (Brondyk et al., 2015; Glatthorn et al., 2012). Thus, school administrators play a key role in developing the efficacy beliefs of staff members and fostering teacher leadership (Donohoo, 2018; Yoon, 2016).

Curricular reforms in secondary settings take place at department levels and new initiatives may challenge the identity and culture of the department (Sutton & Knuth, 2020). The departmental culture is developed and maintained by teacher leaders in the department, which Sutton and Knuth (2020) found influences how individual teachers interpret, adopt, and implement new initiatives. Several researchers echo this finding, citing teacher change agents position themselves in relation to their peers (Kunnari et al., 2018; Leander & Osborne, 2008; Lukacs, 2015). Teacher leaders guide change processes as they elicit the participation of their colleagues (Lukacs, 2015) and respond to the voices of their peers (Leander & Osborne, 2008). These practices generate buy-in and shared responsibility among departmental staff members, in turn motivating teachers to vary their pedagogical approaches and embrace reform efforts (Kunnari et al., 2018; Lukacs, 2015). Furthermore, teachers express relief in knowing they have some autonomy when implementing reforms (Glatthorn et al., 2012; Schreiner, 2014; Turnbull, 2002; Valencic-Miller, 2017) and they are more likely to implement and sustain reform efforts when they receive training, resources, and support from developers and administrators (Glatthorn et al., 2012; Turnbull, 2002). Schreiner (2014) recommends school leaders, including teacher leaders, support teachers in finding their passion within the reform, suggesting this helps teachers develop a positive disposition towards change and to avoid taking change personally.

BARRIERS TO CURRICULAR REFORMS

Rogers (2003) refers to the individuals that present barriers and resistance to change processes as the late majority and laggards. Curricular reforms often result in a sense of loss for these individuals which creates barriers to the change process (Schreiner, 2014; Zimmerman, 2006). Teachers may perceive their current assets and skills will become obsolete with the transition to new initiatives (Schreiner, 2014), leading them to feel threatened and therefore resisting the change (Zimmerman, 2006). In addition, teachers often resist change due to timing, both in terms of several changes being introduced concurrently and limited time to collaborate and implement change

(Lukacs, 2015; Schreiner, 2014). Moreover, teachers develop a lack of trust in school leaders and resign from change processes when continual change occurs (Schreiner, 2014).

Knight (2009) suggests "if school leaders understand the nature of resistance, they can improve relationships with teachers and increase teacher implementation of proven practices" (p. 508). Overcoming resistance, then, begins with communication and trust among school leaders and staff (Knight, 2009; Venezia, 2015; Zimmerman, 2006) and Powell and Kusuma-Powell (2015) believe transformational learning needs to occur for change to be implemented. Transformational learning demands individuals analyze their assumptions and the implications of these assumptions, which is followed by cognitive reframing of the proposed reform through modeling and support (Powell & Kusuma-Powell, 2015). Effective school leaders support transformational learning as they recognize the professional expertise of staff members and honor teacher voice through the change process (Knight, 2009; Venezia, 2015; Zimmerman, 2006). These practices increase trusting relationships between school leaders and staff (Knight, 2009), thus allowing for transformational leadership and transformational learning through the curricular reform process.

Leadership in Mathematics

Over the past 10 years, the goals and instructional pedagogy of mathematics shifted from an emphasis on traditional procedural knowledge to conceptual reasoning and understanding within real-world contexts (Hopkins et al., 2017; National Council of Teachers of Mathematics, 2014; Spillane et al., 2018). States responded to these changes by instituting greater standardization and accountability measures (Hollingworth et al., 2017; Leone et al., 2009; Martinez & Amick, 2019; Yongmei et al., 2018). With the increasing emphasis on school effectiveness and standardized testing, Martinez and Amick (2019) claim the role of school leaders also shifted from managerial tasks to include instructional leadership focused on curriculum and pedagogy. This new role required school leaders to acknowledge and support changes in instructional pedagogy from traditional, direct instruction methods to innovative, inquiry methodologies focused on mathematical reasoning (Martinez & Amick, 2019).

LEADERSHIP EFFICACY IN MATHEMATICS

Bennet et al. (2015) and Lochmiller and Acker-Hocevar (2016) expanded upon the complexity of formal leadership roles given leaders' expertise may not be in mathematics content. School leaders with expertise in mathematics support teachers by offering guidance related to mathematical content, mathematical discourse in the classroom, and math-specific instructional pedagogies (Trinter & Carlson-Jaquez, 2018). Conversely, Lochmiller and Acker-Hocevar (2016) reported "principals perceived that their own lack of understanding about math . . . content prevented them from engaging classroom teachers about instructional improvement matters directly" (p. 283). Given this perception, school leaders without mathematical expertise reframe their instructional leadership role in ways that do not require deep understanding of mathematical content (Lochmiller & Acker-Hocevar, 2016; Trinter & Carlson-Jaquez, 2018). These leaders rely on managerial aspects of instructional leadership, such as establishing and supporting departmental structures for collaboration, hiring teachers that display the desired instructional practice, and providing professional learning from outside consultants (Lochmiller & Acker-Hocevar, 2016). Furthermore, these school leaders often provide deductive feedback to teachers, focusing on general instructional practices and classroom management (Trinter & Carlson-Jaquez, 2018).

However, Martinez and Amick (2019) found teachers rely on instructional support from on-site school leaders, emphasizing the need for leaders to develop skills and understandings in various content areas to complete evaluations and provide feedback to teachers (Trinter & Carlson-Jaquez, 2018). Research suggests targeted professional development for school administrators can strengthen leaders' mathematical content knowledge and pedagogy (Martinez & Amick, 2019) and increase their ability to notice students' mathematical thinking and reasoning when conducting observations and evaluations (Bennet et al., 2015). When such professional learning opportunities are not available, Trinter and Carlson-Jaquez (2018) recommend school leaders seek out colleagues with expertise in mathematics and include these individuals as observers when appropriate. These opportunities for school leaders to grow professionally in specific content areas are critical given the importance and value teachers place on content-focused feedback (Martinez & Amick, 2019; Trinter & Carlson-Jaquez, 2018).

LEADERSHIP IN MATHEMATICAL REFORMS

It is important for school leaders to provide guidance for reform efforts by first developing an understanding of the culture and history of mathematics instruction in their schools (Eacott & Homes, 2010). The mathematics culture is defined by a shared vision and philosophical beliefs, which are often observed through pedagogical practices deeply rooted in the history of traditional mathematics (Eacott & Homes, 2010). Barnes and Toncheff (2016) suggest leaders establish a mathematics leadership team to evaluate the current vision for mathematics instruction and to collaborate in forming a new vision "that honors the mathematics program's current realities and fuels program improvement" (p. 27). Once the vision is established, it is critical to maintain the math leadership team as the guiding coalition for mathematical reforms (Barnes & Toncheff, 2016; Kotter, 2012).

Administrative school leaders often approach mathematics instruction and reform through organizational structures when their background is not in mathematics (Hopkins et al., 2017; Spillane et al., 2018). For example, district and school administrators intentionally select individuals as informal leaders to serve as a bridge when implementing reforms in mathematics (Hopkins et al., 2017; Spillane et al., 2018). Teachers and staff members serve as informal leaders as they facilitate professional dialogue and collaboration to support the development of instructional practices in mathematics (Barnes & Toncheff, 2016; Chapman et al., 2013). Thus, leaders leverage organizational structures and collaborative teams to reform mathematical pedagogies embedded within the school's culture (Barnes & Toncheff, 2016; Hopkins et al., 2017).

Summary

PK–12 schools are faced with an unprecedented number of changes, often requiring school leaders to act as transformational change agents as they influence the attitudes, beliefs, and behaviors of school staff (Bass, 2000). As Burns (1978) suggests, the demands of such complex change "requires that we consider the totality of decision-making by leaders at all levels and in all the interstices of the polity" (p. 415). Thus, this phenomenological study sought to capture the experiences of secondary school leaders across different hierarchical levels as they navigated the complexities of a curricular reform process in mathematics.

Methodology

This study was guided by a transcendental phenomenological research design, the primary purpose of which is to capture the universal essence of a phenomenon (Creswell & Poth, 2018). Transcendental phenomenology offered an opportunity to capture the essence of secondary education leaders' experiences while engaging in a mathematics curricular reform process. Semi-structured interviews and focus groups were used to collect the lived experiences of the participants. Moustakas' (1994) explicit approach to transcendental phenomenology provided an outline for analyzing and synthesizing data, leading to the identification of threaded themes which formed the unified description of the study's findings.

Context

The setting for this study was a large, urban school district in a rural Midwestern state. Secondary schools in the district included middle schools, serving approximately 3,000 students in 6th–8th grades, and high schools, serving approximately 4,000 students in 9th–12th grades. In the 2019–2020 school year, the mathematics departments in the secondary schools moved through the curriculum adoption process. The new math curriculum was implemented within all middle and high schools during the 2020–2021 school year. Thus, mathematics and secondary schools provided the context for this study in examining leadership practices and beliefs during the implementation of a curricular reform.

Participants

The common phenomenon in this study was the mathematics curricular reform, but additional qualifying criterion were used to identify participants that offered insights into the research questions outlined for the purpose of this study (Creswell & Poth, 2018; Moustakas, 1994). Those individuals meeting the criteria and consenting to participation were selected and interviewed. All participants partaking in the interview process were invited to participate in a focus group aligned to their leadership role. As noted, participants held different leadership roles and these roles were integral in the study's data analysis. Table 1 displays the participants' profiles.

Data Collection

Potential participants were emailed to invite them to participate in this research study. The email detailed the purpose and nature of the study, described the expectations for participation, and provided the informed consent form as an attachment. Data was collected from consenting participants through one-on-one, semi-structured interviews. The Individual Interview Protocol (Appendix A) provided an outline of questions aligned to the study's research questions and additional questions were asked to prompt

Table 1: Participant Profiles

Name	Leadership Role	Profile
Colin	Teacher	**Context:** High school classroom teacher **Background:** Bachelor's in math, science, and physics education **Courses Currently Taught:** Geometry, Probability and Statistics, and Transition to College Math **# Years in Current Role:** 6 years
Cassandra	Teacher	**Context:** High school classroom teacher **Background:** Bachelor's in math; Master's in education with an emphasis in mathematics **Courses Currently Taught:** Algebra 2 and Precalculus **# Years in Current Role:** 7 years
Andrew	Teacher	**Context:** High school classroom teacher **Background:** Bachelor's in marketing; master's in business administration; Teaching certification in secondary mathematics **Courses Currently Taught:** Algebra 1 and Bridge to High School Mathematics **# Years in Current Role:** 10 years
Chris	Teacher	**Context:** Middle school classroom teacher **Background:** Bachelor's in math and science education **Courses Currently Taught:** 6th grade **# Years in Current Role:** 6 years
Victor	Teacher	**Context:** High school special education teacher **Background:** Bachelor's in engineering; teaching certification in mathematics; Master's in curriculum and instruction; Specialist degree in educational administration **Courses Currently Taught:** High school special education **# Years in Current Role:** 9 years
Micah	Dean	**Context:** Middle school dean **Background:** Bachelor's in physical education, health, and biology; Master's in administration **# Years in Current Role:** 2 years
Natalie	Dean	**Context:** High school dean **Background:** Bachelor's in history education; master's in leadership and administration **# Years in Current Role:** 1 year
Tamaya	Assistant Principal	**Context:** Middle school assistant principal **Background:** Bachelor's in social studies and English education; Doctorate in educational administration **# Years in Current Role:** 2 years
Dan	Assistant Principal	**Context:** High school assistant principal **Background:** Bachelor's in secondary social sciences education; Master's in school administration **# Years in Current Role:** 9 years
Kelly	Principal	**Context:** Middle school principal **Background:** Bachelor's in elementary education and special education; Master's in administration and special education administration **# Years in Current Role:** 5 years
John	Principal	**Context:** High school principal **Background:** Bachelor's in elementary education and secondary social studies education; Master's in administration **# Years in Current Role:** 15 years

for clarity as needed. In addition, focus group sessions were held aligned to the following leadership roles: principals, deans and assistant principals, and teachers. The Focus Group Protocol (Appendix B) prompted participants to review the unified description compiled from the individual interviews and engage in a dialogue about their experience within the curricular reform process.

Data Analysis

The transcendental phenomenological data analysis methods outlined by Moustakas (1994) guided the analysis within this study. Moustakas (1994) details four phases in the data analysis process: transcription, horizontalization, textural and structural descriptions, and unified description. Recordings were transcribed by a digital service and the researchers reviewed the transcriptions a minimum of three times. Meaning statements were analyzed and coded into themes aligned to the research questions guiding the study. The coded themes were used to develop rich textural and structural descriptions of the study's findings. These descriptions were synthesized into a unified description and shared with the focus groups as a method of peer debriefing. Focus group participants reviewed the unified description, adding further clarity and expounding upon their experiences. They also discussed the similarities and differences among the leadership roles. The researchers used the focus group transcriptions to elaborate upon the themes detailed in the unified description. In addition, the focus group participants provided recommendations for future curricular reform processes and this was added as a concluding theme within the unified description. The resulting unified description provided the findings of this study.

Findings

The study's emerging themes were identified in relation to the study's research questions. Nine themes surfaced from the individual interviews and focus groups during the data analysis process. In addition, focus groups addressed recommendations for future curricular reforms and this is presented as a concluding theme.

TRANSFORMATIONAL LEADERSHIP

Participants were asked to consider and reflect upon how they exhibited transformational leadership practices during the mathematics curricular reform through guiding questions. Through these practices transformational leaders build relationships that stimulate followers' self-worth and motivation (Bass, 1997; Leithwood & Sun, 2012; Minckler, 2014), which in turn influences followers to accomplish more and to move beyond their own self-interests for the good of the organization (Northouse, 2016). Four themes related to transformational leadership practices emerged through the data analysis process: culture and collaboration, shared leadership, motivation and innovation, and supportive considerations. These transformational leadership themes were further divided into sub-themes given the lived experiences described by the study's participants. Table 2 displays the themes and sub-themes related to transformational leadership practices.

Culture and Collaboration. As leaders in the study elaborated on their experience through the implementation of the curricular reform, several leaders, especially teacher leaders, alluded to the importance of culture and collaboration. Five sub-themes emerged regarding leaders' roles in establishing the culture and collaborative practices within their schools.

District Information. Two teacher leaders in the study explained the importance of sharing information from district committees with colleagues at their schools. *Andrew* described his role as an "information disseminator," stating, "There are some conversations that happen that don't involve everyone, and I try to make sure that everyone is on the same page and is given that information." Teacher leaders in this study fostered connections with colleagues and communicated organizational goals throughout the curricular reform process by sharing information between district level committees and their individual schools.

Visibility and Modeling. Participants from all leadership roles indicated visibility and modeling were important transformational leadership practices throughout the mathematics reform as these factors impacted the culture and collaboration within their schools and math departments. *Colin* explained, "I guess just making sure that I'm visible, that my colleagues who I know are doing great things are visible." He expanded upon this comment detailing how he develops resources and emphasizes important components of the curriculum by "spreading the word." *Tamaya,* an assistant principal, offered similar insights from an administrative perspective, stating, "We really work as a team, but we also ask our teachers to work as a team, so we have to model that."

Sharing Information and Resources. Many teacher participants articulated they acted as role models to promote

Table 2: Transformational Leadership: Themes and Sub-Themes

Research Question	Themes	Sub-Themes
How do secondary school leaders exhibit transformational leadership practices during a curricular reform?	Culture and Collaboration	District Information
		Visibility and Modeling
		Sharing Information and Resources
		Lead Learner
		Hiring and Placement
	Shared Leadership	Non-Hierarchical
		Trust
		Empowering Leaders
		Fostering Teacher Leadership
	Motivation and Innovation	Instructional Expectations
		Implementation Expectations
		Modeling Innovation
		Flexibility
		Honesty
	Supportive Considerations	Listening and Responding
		Offering Support

culture and collaboration in their schools by sharing information and resources. *Andrew* explained, "I try to share everything that I'm making and try to get the others included." Teacher leaders also commented on their practice of engaging in frequent, informal dialogue with colleagues. This practice involved sharing successes and challenges when implementing the new math curriculum. Other teachers referred to an "open-door" culture in which they felt comfortable seeking out advice and help from their fellow colleagues that furthered the implementation process. *Cassandra* detailed, "Our department works so well together that I don't feel like it's something my leadership role has had to play a part in, we just kind of built that relationship with each other." Culture and collaboration were established prior to the curricular reform process in this study, but the role of leaders was to continue fostering such elements within their school settings by sharing information and resources.

Lead Learner. Conversely, an assistant principal and principals in the study explained how they fostered culture and collaboration by being lead learners and learning alongside the teachers. *Tamaya* described her philosophy, stating, "I think being lead learners is number one…Because we expect our teachers to [engage in learning], it's only appropriate that we would do it." Based on the practices articulated by administrators, it is important for administrators to be lead learners and learn about the content and curriculum being implemented when engaged in a reform in their school settings. This, in turn, encouraged teachers to grow and learn through the process as well.

Hiring and Placement. Participants commented on the importance of hiring staff that would align with the culture of the school and placing staff in leadership roles that would drive the curricular reform process. *Cassandra* shared how hiring new staff transformed the math department at her school, stating, "We became the majority, the people who wanted to collaborate, we slowly became the majority…With every new hire, they just saw that was the expectation." *Kelly*, a principal, also described her role in selecting teacher leaders to guide the reform, explaining, "With the rollout of math, I really felt like we had everybody in the places they needed to be." Hiring and placing teachers in various roles proved to be a key practice in transforming school cultures, but also in implementing the curricular reform in math.

Shared Leadership. Shared leadership emerged as a theme as mathematics teachers were viewed as the experts to guide the curricular reform. John, a principal, stated, "Math teachers are math majors… of course we would want them to be the primary decision makers on what curriculum we should adopt. And I think that's important too because it also holds them accountable for results." The sub-themes of shared leadership were: non-hierarchical structures, trust, empowering leaders, and fostering teacher leadership.

Non-Hierarchical Structures. Several participants referred to the non-hierarchical structures within their schools, implying a shared leadership system was in place. Teacher leaders expressed they did not view their leadership role as being different than their colleagues. *Cassandra* shared, "I don't see myself as in any different role than anybody else in my [course] group for instance." *Chris* communicated a similar perception of the structures at his school, stating, "I feel like we don't really have leaders here because it just kind of seems like we all just collaborate, like this is what we do." One of the deans, *Natalie*, explained how she believed administrators in her building helped minimize the perception of a hierarchy, noting, "It's not the hierarchy of we're in charge, we're the admin so we make the decisions…I like to view it as a roundtable, where everybody has the time, and everybody respects everybody's communication." These perceptions reflect shared leadership structures rather than a positional hierarchy, which in turn influenced the collaboration and communication throughout the curricular reform process.

Trust. Trust was only mentioned by the administrative participants as they communicated this was key to their role as transformational leaders. *Tamaya* and *Tom* described their need to trust in the teacher leaders serving on district committees to communicate and guide the curriculum implementation within their schools. Tom stated, "My biggest role is to trust the people that are on those committees and in those leadership roles to make those suggestions." Within the context of this study, such trust was utilized to promote teacher leadership.

Empowering Leaders. Deans, assistant principals, and principals stressed that empowering teacher leaders was a key practice they engaged in as transformational leaders. *Dan* claimed, "That is the most important thing we can do, is make people feel valued, feel like they're giving a large contribution." *Kelly* expanded on how she empowered an instructional coach to be a leader for the math teachers, explaining, "I'm providing her that support and the leadership opportunities…It's really empowering her to be able to do her job." John, a principal, suggested this transformational leadership practice also fosters accountability to move the reform process forward. He explained, "I think the more we invest in that leadership aspect in our buildings, the more people take ownership and responsibility."

Fostering Teacher Leadership. Fostering teacher leadership was expressed only by those in administrative roles. Administrative participants articulated that transformational leaders needed to foster teacher leadership when cultivating shared leadership structures in their buildings. *Dan* shared, "As far as teachers, we know who our teacher leaders are. We want to foster their growth just as much as we possibly can." *Dan* and *Tom* described how teachers valued their colleagues as experts in the field and as a result, added a measure of accountability. Thus, one of the key practices of administrative, transformational leaders in this study was to foster the leadership capacities and roles of teachers in their buildings.

Motivation and Innovation. The study's participants shared several ways in which they addressed motivation and innovation throughout the implementation of the curricular reform. These practices organized into five sub-themes: instructional expectations, implementation expectations, modeling innovation, flexibility, and honesty.

Instructional Expectations. Teacher leaders communicated their primary practice related to motivating their colleagues centered around emphasizing instructional expectations. *Colin* explained how he continually stressed pedagogy and the expectations associated with best practices, stating, "I'm always kind of making sure to kind of push that narrative of are we doing what's right, are we making the right decisions, making the right choices." Other teacher leaders shared the importance of having similar goals and pacing related to student learning. *Cassandra* explained how these expectations fostered collaboration, sharing, "I think having the structure and the expectation that we deliver the same material at a similar time has really helped because it does force you to collaborate, because now guess what, you're teaching the same thing."

Implementation Expectations. The administrative participants conveyed that their leadership role associated with motivation focused on maintaining the expectations regarding the implementation of the curriculum. *Tamaya* shared her experience in communicating the implementation expectations with teachers, explaining, "But sometimes you also have to stay firm and say we're doing it…I know it's hard, but the benefits are here, and then explain the why, explain the benefits, explain how it's going to help kids." In addition, *Tamaya* and *Tom* referred to the importance of actionable steps throughout the curricular reform process, emphasizing that the expectations for implementation be put into action within classroom settings.

Modeling Innovation. Participants perceived they encouraged innovation through modeling their own willingness to change and try new things. Furthermore, the teacher leaders described how they were transparent and willing to share what was and was not successful given changes in their instructional practices related to the implementation of the new math curriculum. *Andrew* stated, "Trying something for the first time sometimes can be intimidating, so knowing someone else has tried it…can help them feel like they can try something." Tom, a principal, articulated his practice of providing teachers opportunities to observe other teachers to foster innovation. Modeling innovation and risk-taking were transformational leadership practices utilized by participants to encourage similar behaviors in their fellow colleagues.

Flexibility. Several participants commented on the need to convey to teachers that there was flexibility in implementing the new math curriculum. Participants stressed that teachers need to understand the curriculum materials can be adapted to meet their instructional needs and, more importantly, the needs of their students. *Dan* and *Tom*, both administrators, explained how they reminded teachers that while the "what" is taught may not be in their control, the "how" content is taught is something they can adjust within their teaching practice.

In addition, two principals explained how flexible scheduling influenced innovative teaching practices, although in two different manners. *John* described how common planning was necessary for teachers to explore new methodologies, stating, "We can't tell people to invest in each other and help each other be better teachers and share instructional strategies if we don't give them the time to do it." *Kelly*, on the other hand, explained how block scheduling created opportunities for innovation in the classroom setting. These principals believed scheduling was a practice they could utilize to provide opportunities for innovation.

Honesty. A dean, assistant principal, and principal acknowledged their role in providing honesty during the curricular reform to further inspire innovative teaching practices. *Natalie* shared, "Understanding yes, it's something new, it's nerve-wracking. You don't know what the outcomes are because we've been in a certain curriculum for so long." Administrators believed acknowledging teachers' fears and reservations throughout the reform process allowed for transparency and encouraged teachers to adjust their current beliefs and practices for the good of the organization.

Supportive Considerations. Participants in the study communicated practices in which they offered support to teachers engaged in the curricular reform process. These supportive elements fell into two sub-themes: listening and responding and offering support.

Listening and Responding. Listening and responding were practices heavily referenced by administrative leaders in the study. Only one teacher leader referred to listening and responding as a method of support and he spoke in terms of his assistant principal's practice rather than his own leadership practice. *Andrew* emphasized how valuable such support was from his assistant principal, explaining, "With my assistant principal, when he asks me about how things are going, I know that at least it's on his mind. So, I know that if I need to approach him, I know that he's thinking about it." *Tom*, a principal, echoed the importance of listening and responding when leading change, stating, "I learned that you can initiate it, but if you don't provide the support, it defaults right back to what the comfort was, we close the door, we do what we were always comfortable with."

Administrators in the study perceived they engaged in transformational leadership practices when they responded by providing the necessary support and guidance to move the implementation of the curricular reform process forward. *Kelly,* a principal, articulated her philosophy in supporting teachers throughout the implementation process, explaining, "Teachers are worried about what their performance is going to be. And I have approached all of that…as this is an opportunity. You're not going to fail at this because it's my job to support you, and if you are unsuccessful then I'm not doing my job." Additionally, administrative leaders commented on their role in listening and responding to the personal and emotional needs of teachers, stressing the importance of considering the mindsets of the teachers throughout the curricular reform. Administrators played a key role as they listened and responded to teachers throughout the curriculum implementation, offering teachers reassurance that they would be successful through the reform process.

Offering Support. The study's participants articulated diverse ways in which they offered support to teachers throughout the implementation of the new curriculum. Teacher leaders described how they extended invitations for support to their colleagues. *Chris* stated, "We just let them know we can help them out if they need it." *Colin* echoed this practice, further sharing how he provides support to his peers by offering reassurance when they voice concerns or questions. These comments suggested teacher leaders most often invited others to come to them for help when needed but that they rarely sought out teachers to provide individualized support.

On the other hand, administrative leaders emphasized how they sought out teachers to offer support as a key practice in their role as transformational leaders. *Dan* explained:

> I believe it's my job to get out of this room as often as I can and go see people teach and go watch kids learn. That's the only way I can figure out what's going on. If I wait for people to come to this door, that is such a tiny little funnel…and that's not appropriate. I need to go out to them.

Furthermore, *Dan, John,* and *Natalie* indicated that the teachers needing help are often the one's most reluctant to ask for help, thus stressing the need to seek out these teachers. Administrators also noted their practice in providing feedback to teachers as an element of offering support. *Tamaya* described her role in providing feedback to teachers as a method of moving instructional practices forward. Feedback was a powerful tool for these administrators to offer support to teachers within and beyond the scope of the curricular reform.

BARRIERS

Participants were asked to describe the barriers they perceived existed throughout the implementation of the curricular reform. Through the data analysis process, three themes emerged: physical barriers, social barriers, and leadership barriers. These barriers are further divided into sub-themes given the lived experiences detailed by the study's participants. Table 3 displays the themes and sub-themes related to the barriers of the curricular reform.

Physical Barriers. Physical barriers are defined as objects or structures that may occlude the educational environment. Teacher leaders in the study overwhelmingly noted more physical barriers than deans, assistant principals, or principals. An assistant principal and principal both commented that they "can't think of any" physical barriers. The physical barriers that were described through the data collection process fell into the following sub-themes: pandemic, time, planning, technology, and policies and proximity.

Table 3: Barriers of the Curricular Reform: Themes and Sub-Themes

Research Question	Themes	Sub-Themes
What are the barriers of a curricular reform as perceived by secondary school leaders?	Physical Barriers	Pandemic
		Time
		Planning
		Technology
		Policies and Proximity
	Social Barriers	Instructional Practice
		Communication and Collaboration
		Sustaining Change
		Personal and Emotional Factors
	Leadership Barriers	Defined Roles
		Administration and Content
		Administration and District Support

Pandemic. Given the COVID-19 pandemic, teachers, deans, and assistant principals all referred to the health crisis as an added barrier to the implementation of the new curriculum. *Cassandra* noted the additional challenges, stating, "The levels that we're in are constantly changing which means our instruction is constantly changing." She referred to the levels associated with distance learning and how these changes impact instruction. Curricular reform alters instruction in and of itself, but the pandemic compounded the complexity of designing instruction.

Time. Time was the most cited physical barrier in the study and was mentioned by members from all leadership roles. Participants referred to the barrier of time in terms of covering content in the classroom, collaborating with peers, and learning the new curriculum. *Andrew* expanded upon this barrier, suggesting time also impacted one's ability to be innovative. He shared, "I think [time] limits our ability or willingness to think outside the box or try something, because we're so pressed for time, or at least we feel like we're so pressed for time." He alluded to the idea that education professionals often perceive they are pressed for time, which may result in resistance to change and further hinder curricular reform processes.

Planning. Several teacher leader participants commented on the physical barrier of planning instruction with a new curriculum. *Cassandra* stated, "The other barrier is it's a ton of work the first year…You have to stay a couple steps ahead of your students and know where it's going." *Andrew* echoed *Cassandra*, affirming, "You don't know necessarily what's coming up, where this is going, and have the time to really dig into that, at least in the first year or two." The lack of experience with the curriculum resulted in a barrier for teachers as they prepared instruction for their students using the new curriculum materials.

Participants from each focus group elaborated on how scheduling structures in their buildings allowed them to address planning barriers throughout the implementation of the curricular reform. *Cassandra, Tamaya*, and *John* shared how their buildings created schedules that provided for team planning, which in turn fostered collaboration through the implementation of the new math curriculum. *John*, a principal, detailed his experience and the importance of such scheduling structures, stating, "If we're going to develop and implement new curriculum and then we want teachers to collaborate, we want to build trust…if we give them [planning] time, you'll see all those things foster."

Technology. While technology proved to be a common barrier among participants' experiences, it was not access to technology that they described, rather, participants expressed barriers in how the technology could be used to support instruction. For example, teachers noted that touch-screen laptops would be beneficial and limitations with regards to the functionalities of online homework. *Tamaya*, an assistant principal, also expressed how the incorporation of technology presented a barrier between the teacher and students when protocols were not in place. Participants articulated the importance of not only considering access to technology, but also how technology was to be used when implementing the new math curriculum.

Policies and Proximity. Policies and proximity were not referenced frequently, but a few teacher leaders commented on the barriers these elements presented when implementing the new curriculum. *Colin* shared how he felt policies, such as grading requirements, limited his ability to propel the reform process forward, stating, "I feel like the policies have kind of forced us into those older ways…I can't do all the cool things I want to do because I'm so tied into [policies]." In addition, *Andrew* and *Cassandra* described proximity as a barrier to collaboration given teachers at their respective schools were physically distanced from colleagues in the math department that taught the same courses. They described how proximity limited the extent to which resources and informal dialogue were shared among colleagues regarding their daily experiences in implementing the curriculum.

Social Barriers. Social barriers are defined as personnel, emotional, and relationship elements that may obstruct the educational environment. Participants from all leadership roles noted social barriers they perceived influenced the curricular reform in their school settings. Four sub-themes of social barriers emerged: instructional practice, communication and collaboration, sustaining change, and personal and emotional factors.

Instructional Practice. Curricular reforms are often accompanied by new instructional methodologies. Several participants indicated this presented a barrier when engaging teachers in the reform process. *Tamaya* shared, "Sometimes I think we do what's convenient for adults in schools, not what's best for kids. It's convenient to stay the same way, it's convenient to not have to change because it's hard, but that doesn't get you results." Participants stressed the importance of changing more than just the physical curriculum materials through the implementation process, but also reforming instructional practices to better meet the needs of students.

Andrew and *Natalie* shared how they personally tried to address the social barrier of their colleagues' mindsets and instructional practices by sharing ideas and resources. *Natalie*, a dean, explained that the reform process and the implementation of new instructional practices also required students to alter their mindsets and approach to learning. She stated, "Trying to get [students] to buy into math, that's a little frustrating for some teachers as well because…they have that mental barrier inside of them right now."

During the focus groups, *Dan* and *John*, both administrators, voiced how scheduling and collaborative structures addressed social challenges associated with instructional practices. John explained, "The more teachers collaborate, especially on new curriculum that's brought in, the better the teaching techniques, the better the units and the lessons that are, that are developed and prepared, and the better outcomes for the kids." Curricular reforms are contextualized by change, including changes in instructional practices. Leaders in this study suggested these changes posed as barriers for teachers and students as they were presented with new approaches and instruction in mathematics, but they also employed methods to address such barriers throughout the reform.

Communication and Collaboration. Participants from all leadership roles commented on factors related to communication and collaboration that proved to be social barriers through the curricular reform process. *Chris* emphasized the importance of relationships with his colleagues when engaging in the curricular reform process as he detailed instances in which teachers may have refrained from asking questions in fear of being judged. *Tom*, a principal, communicated that he tried to address this barrier during the hiring process as it impacted collaboration efforts beyond the curricular reform. John, also a principal, shared that collaboration can play a role in overcoming other barriers, explaining, "I think the teachers that are struggling are going to get better because they're working with other groups or other teachers in their departments."

Participants elaborated on the communication and collaboration barrier during the focus groups, indicating that while these practices were strong within grade levels and common courses, they were limited across courses, the district, and leadership levels. The teacher leaders voiced the strength of the culture and collaboration with colleagues teaching the same courses. However, *Cassandra* and *Colin* expanded upon this, citing that the physical barrier of proximity impacted collaboration and communication across courses within their school buildings. In parallel, while individuals from all leadership roles highlighted the culture and collaboration within their buildings, the teacher focus group and the dean and assistant principal focus group conversed about such practices being limited across the district. Furthermore, participants voiced the need to expand communication and collaboration across leadership levels to support the curricular reform process. *Colin*, a teacher leader, stated, "[Administrators] don't know what we need, and we haven't necessarily told them what we need." This connected to *Dan's* insights from an assistant principal perspective as he explained, "If you're an administrator, you're seen as being on the other team, oftentimes, and not nearly as approachable as you believe yourself to be, and that's unfortunate." These comments highlighted the disconnect in communication and collaboration between teachers and administrators and administrators extended this disconnect to communication challenges between administrators and district leaders. Given the participants' experiences, communication and collaboration proved to be a barrier contributing to the implementation of the curricular reform.

Sustaining Change. A teacher and an assistant principal referred to sustaining change as a social barrier. *Dan* described, "Sustaining those has got to be a very, very high priority… Reminding each other that we're not just going to try this thing until it gets replaced with that thing… because then your investment level is very low." He suggested if the investment level is low, teachers will not engage in the curricular reform or revert to previous curricular practices.

The dean and assistant principal focus group and the principal focus group expanded upon the processes necessary to sustain change initiatives. *Micah, Tamaya,* and *Tom* referred to hiring processes and retaining staff to maintain the momentum of change efforts, including the implementation of the mathematics reform. Tom shared, "We invest a lot of time, money into staff, and then if we can't keep them in our district from one building to another or even at your own building, it hurts to keep the initiative moving forward." The administrative leaders perceived processes to retain staff were critical in sustaining change efforts.

Personal and Emotional Factors. The final sub-theme, personal and emotional factors, was only noted by those in administrative roles. Kelly, a principal, shared personal and emotional factors she observed in her teaching staff as they implemented the curricular reform, explaining, "I think it's confidence…I would say it's a first year thing. We're all going to be unsure and not have the confidence, but I think as we move into the next year we just build on that confidence." She also expressed how she addressed these barriers, stating, "Anytime we're rolling out something new you're going to go through those periods of frustration, and…that's where we need to provide [teachers] that self-care."

Leadership Barriers. As participants described their experiences within the curricular reform process, leadership barriers emerged as a common theme, but the sub-themes were unique to their leadership roles. The sub-themes referenced by participants included defined roles, administration and content, and administration and district support.

Defined Roles. This sub-theme was articulated by *Cassandra*, a teacher leader. She shared her experience, describing the barriers she faced in guiding the implementation of the curricular reform at her school. *Cassandra* explained, "I don't think that we have a clear purpose of the leadership team, and then also, who they are and kind of how to roll out this curriculum. So, I think not having clear guidance on what our role is." *Cassandra's* frustration was communicated as she was unclear of her leadership role throughout the implementation of the curricular reform.

Administration and Content. Teacher leaders and deans in the study both expressed administration's math content knowledge as a potential barrier to leading the curricular reform process. *Colin* shared, "I think a lot of it is just [administrators] don't know. I would like them to come in and see what it's like." *Victor* echoed *Colin,* stating, "All of our administration comes from teaching disciplines other than math." *Micah* and *Natalie*, both deans, communicated that they needed to understand the materials and content better to be able to support teachers. While participants communicated that being a content expert was not necessary for those in administrative positions, they also stressed the importance of administrators developing familiarity with the content and curriculum being implemented through the reform process.

Administration and District Support. Principal leaders conveyed district support as a barrier to their leadership roles within reform processes. District support referred to individuals such as the superintendent, assistant, superintendent, and curriculum director. *Tom* shared, "I'm only middle management. So, [teachers] will try to go over your head at times, and if they can find support there then it kind of derails what we're trying to do here." Principals indicated they needed support throughout the curricular reform process and that this support comes from the district level. The principals suggested lack of district support could potentially hinder the leadership role of principals in supporting the implementation of the curriculum within their school settings.

EFFICACY

During the interview and focus group processes, participants were asked to describe their efficacy beliefs in relation to leading the implementation of the curricular reform and whether the content area, in this case mathematics, further influenced these beliefs. Relationships emerged as a common theme that influenced participants' efficacy in leading the implementation of the reform, while experience surfaced as a theme with regards to the impact of mathematics on one's efficacy beliefs. Furthermore, several sub-themes of relationships and experience emerged

Table 4: Leaders' Efficacy Beliefs: Themes and Sub-Themes

Research Question	Themes	Sub-Themes
How do secondary school leaders' perceived efficacy beliefs influence the nature and extent of their role during a curricular reform?	Relationships	Voice and Credibility
		Belief and Support
	Experience	New Curriculum
		Grade/Course
		Administration

and aligned to the leadership roles of the participants. Table 4 presents the themes and sub-themes related to leaders' efficacy beliefs.

Relationships. Throughout the individual interviews, relationships emerged as a theme that influenced one's efficacy beliefs regarding their leadership role during the curricular reform. The sub-theme that emerged from teacher leaders was voice and credibility, while the sub-theme that arose for those in administrative positions was belief and support.

Voice and Credibility. Teacher leaders spoke about their voice and credibility throughout the implementation of the curricular reform. Teachers commented on their positionality and serving on the district-committee, describing how this offered them credibility in their relationships with colleagues. *Andrew* explained, "Being involved in the processes and being willing to be involved in the process, knowing others aren't, I think gives me the position to speak up." In addition, *Chris* described how his relationships with colleagues influenced his self-concept and willingness to voice his thoughts throughout the implementation process.

Two teacher leaders also reflected on their credibility given their relationships with colleagues and discussed how this challenged their efficacy beliefs. *Cassandra* commented, "Where I don't feel confident is inspiring that same ambition or excitement for a curriculum. I guess, if I'm excited about it, I hope my excitement can inspire others." Teacher leaders in the study expressed their need to develop relationships in which they feel they have a voice and credibility amongst their colleagues. These factors influenced their self-efficacy beliefs that either bolstered or hindered their role as teacher leaders throughout the implementation of the curricular reform.

Belief and Support. Conversely, the deans, assistant principals, and principals in the study spoke about their efficacy in terms of their belief in the curriculum and support for teachers. The administrative leaders communicated that when they developed an understanding of the new curriculum and believed in the curricular reform being implemented, this in turn cultivated their own efficacy beliefs that influenced their relationships with teachers when leading the implementation of the math reform. In addition, administrators indicated their strengths and efficacy beliefs came from offering support to teachers during the implementation.

Experience. Most of the teacher leaders expressed strong efficacy beliefs regarding the mathematics content, while administrators made comments about their lack of mathematics content knowledge. For example, *Natalie* stated, "You know, math is not my strongest adventure in life," and *Dan* acknowledged, "The curriculum side of things is a little outside my comfort level." However, these comments by both teachers and administrators were brief. As the participants reflected on whether mathematics influenced their efficacy beliefs, conversations were centered around the theme of experience with comments organized into three sub-themes: new curriculum, grade/course, and administration.

New Curriculum. Teachers, deans, and assistant principals all expressed limited efficacy during the mathematics curricular reform given their lack of experience with the new curriculum. Teacher leaders expressed challenges regarding their ability to anticipate the direction of the curriculum. *Colin* elaborated on his experience, explaining, "I have to learn it first and that's one thing that is definitely different from last year. Last year…I could know where the conversation was going to go and know where those big mistakes were going to happen." One of the deans and one of the assistant principals expressed similar sentiments, describing their lack of knowledge in the new curriculum.

Grade/Course. Another sub-theme related to mathematics efficacy that emerged from the teacher leaders was their experience pertaining to a specific grade or course level. Teacher leaders expressed their limited efficacy outside of their grade or course and furthermore, that their colleagues in those areas are often resistant. *Colin* commented, "I get a lot of, and understandably, a lot of, 'You don't know what we're doing. You don't have any clue what it's like to teach algebra.' I'm like, you're right, I don't. But, I do know what's best practice." Despite comments from colleagues, he maintained strong efficacy beliefs that extended beyond experience with specific mathematics content to pedagogy and instructional practices.

Administration. The final sub-theme arose from the administrative leaders and reflected the role of their administration experience on their efficacy beliefs as it related to mathematics. Administrative participants reported they did not feel as though they needed extensive efficacy or experience in mathematics content. These sentiments were echoed again within the administrative focus groups. *Dan* and *Kelly* described their roles as instructional leaders, focusing on facilitating processes and offering support throughout the curricular reform. *Tamaya* shared, "'The facilitator is the flow person, not the know person,' and I really love that because I don't feel like I have to be the know person as long as I can facilitate what's going to occur around me." Administrative leaders did not believe they needed to be content experts and felt they should focus on developing their efficacy beliefs to further establish relationships with teachers that would drive the curricular reform process.

As the teacher leader focus group reviewed the administrators' perspective, the teachers explained their administrators trusted them to be the experts and deliver the mathematics content. As *Andrew* explained, "I'm not expecting [administrators] to be content masters or even really understand what we're doing." *Chris* and *Victor* both agreed with *Andrew's* comments, describing how administrators offered valuable feedback regarding universal teaching practices. The teacher leaders expressed appreciation for the trust they were afforded from principals, as *Andrew* stated, "I also appreciate that we're treated as professionals and that we're going to get our stuff done, and we can handle what's thrown at us." The leaders in this study, whether teachers or administrators, articulated similar perceptions in that administrators did not need to possess strong efficacy in mathematical content to facilitate the implementation of the curricular reform in mathematics.

RECOMMENDATIONS FOR FUTURE MATHEMATICS REFORMS

Each focus group was prompted to consider recommendations for future curricular reforms and this dialogue extended beyond the research questions outlined in this study. Much of the dialogue regarding participants' recommendations for future reform efforts addressed considerations of the processes utilized prior to the implementation phase. The teacher leader focus group stressed the need to broaden the pilot and selection process further in terms of time and teachers involved. *Cassandra* explained, "Yes, having one geometry from each school is helpful, but that's not who they're used to collaborating with and so we need more of each team to be a part of that process." Collaboration was a key transformational leadership practice for the teacher leaders in the study, but *Cassandra's* experience indicated collaboration was limited within the scope of the pilot process. In addition, *Andrew* described the need to lengthen the timeframe of the pilot, highlighting the importance of exploring and understanding the technology components prior to adoption and implementation of the new curriculum.

Similarly, participants from the dean and assistant principal focus group offered recommendations for the selection phase prior to implementation, but they focused on the need to consider the range of learners within the mathematics selection process. *Tamaya* stated, "I really feel like a challenge has been…that when we do curriculum adoptions we only address one area. We don't look at the whole big picture of all students, where we're looking at all the tiers." *Micah* echoed her comments, describing the need to consider students that struggle with mathematics and how the curriculum will meet those students' needs.

Discussion

Leading school change, specifically curricular reforms, is a lengthy and complex process. Furthermore, mathematics reforms are cyclical as research and changing demands frequently inspire revisions in pedagogy and instructional design. As a result, school leaders are tasked with continually guiding curricular reform processes in their schools. The transformational leadership approach outlines how school leaders may engage teachers in curricular reform efforts, motivating and nurturing them through the implementation process (Northouse, 2016). Central to the transformational leadership approach is both leaders' and followers' self-concepts (Bass, 2000; Northouse, 2016), which are influenced by one's efficacy beliefs (Bandura, 1989, 1993). However, there is a lack of research exploring the interrelationship between efficacy beliefs and transformational leadership practices. This study's findings suggested there is a relationship between leaders' efficacy beliefs and transformational leadership practices when facilitating a curricular reform.

Overall, leaders in the study shared several behaviors and practices they engaged in throughout the implementation of the curricular reform that aligned to the transformational leadership approach. Bass identified four factors which influence a leader's ability to transform the thinking and actions of followers: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration (Bass, 1985, 2000). In addition, Kouzes and Posner (2017) detailed the need for transformational leaders to be honest, competent, inspiring, and forward-thinking to drive change processes. This study adds to the research as these practices were cited by participants engaged specifically within the context of a mathematics reform phenomenon. Participants from all leadership roles described practices throughout the implementation of the mathematics curricular reform related to culture and collaboration, shared leadership, motivation and innovation, and supportive considerations. Thus, the findings revealed leaders utilize and practice key elements of the transformational leadership approach when engaged in a curricular reform.

The leaders were also asked to expand upon the barriers they perceived influenced the implementation of the secondary mathematics reform. Participants described physical, social, and leadership barriers that emerged at their schools. As focus groups reviewed these barriers, the dialogue shifted to reflect associated transformational leadership behaviors that addressed some of the barriers within the scope of the curriculum implementation and those that could potentially overcome additional and future barriers. For example, administrators stressed the importance of scheduling frequent collaborative opportunities to address resistance associated with implementing new instructional approaches and practices. In addition, multiple focus groups described barriers associated with communication, citing communication was strong within their immediate group of colleagues but limited beyond their given group. It is recommended purposeful opportunities for communication across courses and across schools within the district be scheduled throughout the curricular reform process. Lastly, the administrative focus groups emphasized the importance of retaining staff to sustain change efforts associated with the curricular reform. Administrators enacting transformational leadership practices are attentive and responsive to the needs of their staff to support a positive school culture that is likely to retain staff. The connection between barriers and transformational leadership practices emphasizes the value and power of transformational leadership in propelling curricular reform efforts forward.

Finally, an individual's self-efficacy beliefs affect one's control over their thoughts and abilities (Bandura, 1989, 1993). The study indicated such efficacy beliefs influenced participants' transformational leadership behaviors and practices. Leaders reflected on their efficacy beliefs related to facilitating the curricular reform process and to mathematics content. Participants from all leadership roles expressed how their efficacy beliefs in guiding the implementation of the mathematics curriculum were dependent upon their relationships with teachers engaged in the reform process. Given transformational leadership is defined by the relationship between leaders and followers (Northouse, 2016), it is vital leaders from all roles possess strong self-efficacy beliefs when considering their relationships with teachers if they are to be tasked with leading a curricular reform. In reference to mathematics self-efficacy, participants expressed the influence of experience on their beliefs rather than the mathematics content knowledge itself. Teacher participants articulated their beliefs were dependent upon their instructional experience and administrative participants' beliefs were dependent upon their leadership experience. Most teacher leaders expressed they felt confident in their mathematical content knowledge, but within the scope of the reform process they were less efficacious in delivering math content given they were unfamiliar with the new curriculum. Administrators indicated they did not feel the need to possess strong efficacy beliefs related to mathematics content. Given their positional roles, administrators expressed it was more critical to develop strong efficacy beliefs related to facilitating the reform process and providing support to teachers. Teacher leaders, on the other hand, described how administrators' lack of content knowledge proved to be a challenge at times throughout the implementation of the curricular reform and beyond. However, they did value the administration's trust in their ability to deliver effective mathematics instruction. These findings suggest that while administrators do not require an extensive background in mathematics, expanding their knowledge related to mathematics content and pedagogy may enhance their efficacy as it relates to relationships with teachers and their transformational leadership practices in leading curricular reform processes.

Implications and Conclusion

Research studies, including this phenomenological study, suggest mathematics leaders utilize transformational leadership approaches as they guide change initiatives. The findings of this study expand upon such literature, positioning transformational leadership practices specifically within the context of curricular reforms and in relation to efficacy beliefs. Based on this study's findings, it is recommended that schools preparing for the implementation of a mathematics reform consider the efficacy beliefs of leaders from all leadership roles in relation to their relationships with teachers that will be implementing the new curriculum. Individuals with strong efficacy regarding their relationships with these teachers should be positioned in leadership roles to drive reform efforts. It is also recommended that leaders are afforded the chance to increase their experience with the mathematics curriculum prior to implementation and to expand communication and collaboration throughout the implementation process. In particular, communication and collaboration should be extended beyond common grade levels and courses to include such practices across courses, the district, and leadership levels. If these opportunities are presented, leaders may increase their self-efficacy by deepening their relationships and therefore strengthening their roles as transformational leaders through mathematics reform processes. ✪

References

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175-1184. https://doi.org/10.1037/0003-066X.44.9.1175

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117-148. https://doi.org/10.1207/s15326985ep2802_3

Barnes, B., & Toncheff, M. (2016). *Activating the vision: The four keys of mathematics leadership.* Solution Tree Press.

Bass, B. M. (1985). *Leadership and performance beyond expectations.* Free Press.

Bass, B. M. (1997). Does the transactional-transformational leadership paradigm transcend organizational and national boundaries? *American Psychologist, 52*(2), 130-139.

Bass, B. M. (2000). The future of leadership in learning organizations. *Journal of Leadership & Organizational Studies, 7*(3), 18-40. https://doi.org/10.1177/107179190000700302

Bennet, C. A., Amador, J. M., & Avila, C. (2015). Framing professional conversations with teachers: Developing administrators' professional noticing of students' mathematical thinking. *NCSM Journal of Mathematics Education Leadership, 26*(2), 14-26.

Brondyk, S. K., Cooper, K. S., Hamilton, E. R., Macaluso, M., Meier, J. A., & Stanulis, R. N. (2015). The teacher leadership process: Attempting change within embedded systems. NCPEA *Journal of Educational Change, 17*(1), 85-113. https://doi.org/10.1007/s10833-015-9262-4

Burns, J. M. (1978). *Leadership.* Harper Perennial.

Chapman, S., Leonard, A., Burciaga, S., & Jernigan, T. (2013). A tale of three teachers. T*eaching Children Mathematics, 20*(3), 190-197.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches.* Sage.

Donohoo, J. (2018). Collective teacher efficacy research: Productive patterns of behaviour and other positive consequences. *Journal of Educational Change, 19*, 323-345. https://doi.org/10.1007/s10833-018-9319-2

Dupas, M. J. (2016). *The predictability of selected principal's leadership efficacies, leadership styles, and demographic factors on the academic performance of public schools* (Publication No. 10300305) [Doctoral dissertation, Texas Southern University]. ProQuest Dissertations & Theses Global.

Dyson, M. D. (2019). *The efficacy actions of priority school leaders during the dynamic change of school reform* (Publication No. 13917741) [Doctoral dissertation, Western Michigan University]. ProQuest Dissertations & Theses Global.

Eacott, S., & Homes, K. (2010). Leading reform in mathematics education: Solving a complex equation. *Mathematics Teacher Education and Development, 12*(2), 84-97.

Flood, L. D., & Angelle, P. S. (2017). Organizational influences of collective efficacy and trust on teacher leadership. *International Studies in Educational Administration, 45*(3), 85-99.

Frost, D., & Harris, A. (2003). Teacher leadership: Towards a research agenda. *Cambridge Journal of Education, 33*(3), 479-498.

Glatthorn, A. A., Boschee, F., Whitehead, B. M., & Boschee, B. F. (2012). *Curriculum leadership: Strategies for development and implementation* (3rd ed.). Sage.

Goddard, R. D., & Goddard, Y. L. (2001). A multilevel analysis of the relationship between teacher and collective efficacy in urban schools. *Teaching and Teacher Education, 17*, 807-818.

Harris, A. (2005). Reflections on distributed leadership. *Management in Education, 19*(2), 10-12. https://doi.org/10.1177/08920206050190020301

Hauserman, C. P., & Stick S. L. (2013). The leadership teachers want from principals Transformational. *Canadian Journal of Education, 36*(3), 184-203.

Hollingworth, L., Olsen, D., Asikin-Garmager, A., & Winn, K. M. (2017). Initiating conversations and opening doors: How principals establish a positive building culture to sustain school improvement efforts. *Educational Management Administration & Leadership, 46*(6), 1014-1034. https://doi.org/10.1177/1741143217720461

Hopkins, M., Ozimek, D., & Sweet, T. M. (2017). Mathematics coaching and instructional reform: Individual and collective change. *The Journal of Mathematical Behavior, 46*, 215-230.

Kezar, A. (2018). *How colleges change: Understanding, leading, and enacting change* (2nd ed.). Routledge.

Kitsantas, A., & Ware, H. W. (2011). Predicting teacher commitment using principal and teacher efficacy variables: An HLM approach. *The Journal of Educational Research, 104*(3), 183-193. https://doi.org/10.1080/00220671003638543

Knight. J. (2009). What can we do about teacher resistance? *Phi Delta Kappan, 90*(7), 508-513. https://doi.org/10.1177/003172170909000711

Kotter, J. P. (2012). *Leading change.* Harvard Business Review Press.

Kouzes, J. M., & Posner, B. Z. (2017). *The leadership challenge* (6th ed.). John Wiley & Sons.

Kunnari, I., Ilomaki, L., & Toom, A. (2018). Successful teacher teams in change: The role of collective efficacy and resilience. *International Journal of Teaching and Learning in Higher Education, 30*(1), 111-126.

Leander, K. M., & Osborne, M. D. (2008). Complex positioning: Teachers as agents of curricular and pedagogical reform. *Journal of Curriculum Studies, 40*(1), 23-46.

Leithwood, K. (2016). Department-head leadership for school improvement. *Leadership and Policy in Schools, 15*(2), 117-140. https://doi.org/10.1080/15700763.2015.1044538

Leithwood, K., Mascall, B., Strauss, T., Sacks, R., Memon, N., & Yashkina, A. (2007). Distributing leadership to make schools smarter: Taking the ego out of the system. *Leadership and Policy in Schools, 6*, 37-67. https://doi.org/10.1080/15700760601091267

Leithwood, K., & Sun, J. (2012). The nature and effects of transformational school leadership: A meta-analytic review of unpublished research. *Educational Administration Quarterly, 48*(3), 387-423. https://doi.org/10.1177/0013161X11436268

Leone, S., Warnimont, C., & Zimmerman, J. (2009). New roles for the principal of the future. *American Secondary Education, 37*(2), 86-96.

Lochmiller, C. R., & Acker-Hocevar, M. (2016). Making sense of principal leadership in content areas: The case of secondary math and science instruction. *Leadership and Policy in Schools, 15*(3), 273-296. http://dx.doi.org/10.1080/15700763.2015.1073329

Lukacs, K. (2015). For me, change is not a choice: The lived experience of a teacher change agent. *American Secondary Education, 44*(1), 38-49.

Martinez, J. A., & Amick, L. R. (2019). What educational leaders need to know about early career mathematics teachers. *NCSM Journal of Mathematics Education Leadership, 20*(1), 19-33.

McIntosh, K., Kelm, J. L., & Canizal Delabra, A. (2016). In search of how principals change: A qualitative study of events that help and hinder administrator support for school-wide PBIS. Journal of Positive *Behavior Interventions, 18*(2), 100-110. https://doi.org/ 10.1177/1098300715599960

Miller, R. J., Goddard, R. D., Kim, M., Jacob, R., Goddard, Y., & Schroeder, P. (2016). Can professional development improve school leadership? Results from a randomized control trial assessing the impact of McREL's balanced leadership program on principals in rural Michigan schools. *Educational Administration Quarterly, 52*(4), 531-566. https://doi.org/10.1177/0013161X16651926

Minckler, C. H. (2014). School leadership that builds teacher social capital. *Educational Management Administration & Leadership, 42*(5), 657-679. https://doi.org/10.1177/1741143213510502

Moustakas, C. (1994). *Phenomenological research methods.* Sage.

National Council of Teachers of Mathematics. (2014). *Principles to action: Ensuring mathematical success for all.* NCTM.

Northouse, P. G. (2016). *Leadership: Theory and practice* (7th ed.). SAGE Publications, Inc.

Pietsch, M., & Tulowitzki, P. (2017). Disentangling school leadership and its ties to instructional practices – an empirical comparison of various leadership styles. *School Effectiveness and School Improvement, 28*(4), 629-649. https://doi.org/10.1080/09243453.2017.1363787

Powell, W., & Kusuma-Powell, O. (2015). Overcoming resistance to new ideas. *Phi Delta Kappan, 96*(8), 66-69.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Schreiner, S. L. (2014). *How teachers experience change: A phenomenological case study of a district-wide curricular reform* (Publication No. 3635675) [Doctoral dissertation, Colorado State University]. ProQuest Dissertations and Theses Global.

Spillane, J. P., Hopkins, M., & Sweet, T. M. (2018). School district educational infrastructure and change at scale: Teacher peer interactions and their beliefs about mathematics instruction. *American Educational Research Journal, 55*(3), 532-571. https://doi.org/10.3102/0002831217743928

Sutton, P. S., & Knuth, R. (2020). How high school academic departments impact school reform efforts. *Journal of Curriculum Studies, 52*(1), 118-137. https://doi.org/10.1080.00220272.2019.1624830

Trinter, C. P., & Carlson-Jaquez, H. (2018). An examination of the nature of post-observation feedback provided to middle school mathematics teachers. *NCSM Journal of Mathematics Education Leadership, 19*(1), 3-22.

Turnbull, B. (2002). Teacher participation and buy-in: Implications for school reform initiatives. *Learning Environments Research, 5*, 235-252.

Valencic-Miller, O. V. (2017). *Leaders and change: Leadership behaviors and influence on subordinates' reaction to organizational change* (Publication No. 10642884) [Doctoral dissertation, Indiana Wesleyan University]. Retrieved from ProQuest Dissertations & Theses Global.

Venezia, J. (2015). *Educators' response to change in K-12 education: Factors that impact change efforts* (Publication No. 3664648) [Doctoral dissertation, New Mexico State University]. ProQuest Dissertations and Theses Global.

Yongmei, N., Yan, R., & Pounder, D. (2018). Collective leadership: Principals' decision influence and the supportive or inhibiting decision influence of other stakeholders. *Education Administration Quarterly, 54*(2), 216-248. https://doi.org/10.1177/0013161X17723427

Yoon, S. Y. (2016). Principals' data-driven practice and its influences on teacher buy-in and student achievement in c omprehensive school reform models. *Leadership and Policy in Schools, 15*(4), 500-523. https://doi.org/10.1080/15700763.2016.1181187

Zimmerman, J. (2006). Why some teachers resist change and what principals can do about it. *NASSP Bulletin, 90*(3), 238-249. https://doi.org/10.1177/0192636506291521

Appendix A
Individual Interview Protocol

The following questions guided the interview, beginning with the warm-up questions to gather background information and to help the participant feel at ease. These questions were followed by the interview questions (IQ) that are organized around the study's research questions (RQ).

Warm-Up Questions:

1. What is your educational background?
2. Tell me about your professional experience and roles in the education field.
3. What is your current role in education and how long have you occupied this role?
4. Who is a teacher leader that emerged through the mathematics reform?

RQ 1: How do secondary school leaders exhibit transformational leadership practices during a curricular reform?

IQ 1: Describe your leadership experience and role within the scope of the mathematics curriculum adoption and implementation.

IQ 2: Describe the relationship between you and the teachers engaging in the mathematics curricular reform.

IQ3: Describe the relationship between you and other school leaders (including teacher leaders) in the mathematics curricular reform.

IQ 4: Describe what you perceive as effective leadership behaviors and practices that supported teachers through curriculum reform process.

IQ 5: How do you, within your leadership role, act as a role model to the mathematics teachers implementing the curricular reform?

IQ 6: How do you, within your leadership role, inspire and motivate mathematics teachers engaging in the curricular reform process?

IQ 7: How do you, within your leadership role, encourage innovation and the exploration of new teaching pedagogies within the scope of the mathematics reform?

IQ 8: How do you, within your leadership role, support individual teachers' needs as they implement the new mathematics curriculum?

RQ 2: What are the barriers of a curricular reform as perceived by secondary school leaders?

IQ 9: What do you perceive are the physical barriers (i.e. time, budget, etc.) hindering the implementation of the new mathematics curriculum?

IQ 10: What do you perceive are the social barriers (i.e. culture, relationships, etc.) hindering the implementation of the new mathematics curriculum?

IQ 11: What do you perceive are the barriers that impact leaders' roles in supporting the implementation of the new mathematics curriculum?

IQ 12: How do you, within your leadership role, address these perceived barriers and resistance to the mathematics curricular reform?

RQ 3: How do secondary school leaders' perceived efficacy beliefs influence the nature and extent of their role during a curricular reform?

IQ 13: Describe your level of comfort and confidence in leading the implementation of curricular reforms.

IQ 14: To what extent does your comfort and confidence levels change depending on the content area of the curricular reform? In this case, with regards to mathematics?

Appendix B
Focus Group Protocol

The following questions guided the focus group dialogue as participants review the unified description compiled from the individual interviews.

Focus Group Questions:

1. Upon reviewing the textural description associated with your leadership role, what needs to be added or expanded to clarify your experience of the mathematics curricular reform?
2. Upon reviewing the structural description associated with your leadership role, what needs to be added or expanded to clarify your experience of the mathematics curricular reform?
3. How closely do you feel the description represents your leadership experience within the scope of the mathematics curricular reform?
4. What similarities and differences do you notice between the descriptions for your leadership role and the other leadership roles?
5. Based on the unified description, what recommendations would you offer for future curricular reforms, whether in mathematics or other content areas?

Design and Impact of Flexible, Asynchronous Online Video-based Mathematics Professional Development

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Abstract

In this article, we share the experimental research design and preliminary impact results from the Video in the Middle project, which is adapting existing face-to-face video-based mathematics professional development materials to online two-hour modules that can be used in flexible asynchronous formats: independent, locally facilitated, or developer facilitated. Preliminary research results indicate that teachers appreciated the variety of formats, found the modules useful and engaging, and learned to appreciate and use visual methods for solving problems, including using color to distinguish and highlight the relationship between numeric, algebraic, and geometric models. The benefits of this asynchronous PD became pronounced as the pandemic emerged during the research study and teachers found themselves shifting to remote instruction with little time to prepare.

Incorporating video within the professional development (PD) environment provides an opportunity for teachers to unpack the relationships among pedagogical decisions and practices, students' work, and the disciplinary content (e.g., Borko et al., 2011; Brophy, 2004; Harford & MacRuairc, 2008; Rich & Hannafin, 2009; Rosaen et al., 2008; Sherin, 2007). Collectively viewing and discussing video clips allows for the complexities of classroom practice to be stopped in time, unpacked, and thoughtfully analyzed, helping to bridge the ever-present theory-to-practice divide and support instructional reflection and improvement. In the classroom, teachers must constantly make individual in-the-moment decisions, while viewing video during PD allows them the opportunity to collectively deconstruct and discuss familiar experiences and to actively generate new understandings about content, pedagogy, and student thinking (Cullen, 1991; Korthagen et al., 2001). With video, teachers have the opportunity to observe and study the complexity of classroom life, to reflect on their own instructional decisions, and to integrate multiple domains of knowledge to solve problems of practice (Blomberg et al., 2013). Recent comprehensive reviews of the literature on video in PD point to the value of video as a learning tool that can promote improvements

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in instructional practice (Gaudin & Chaliès, 2015; Major & Watson, 2018). In addition, cognitive science research suggests that strongly connected learning and transfer situations improve knowledge transfer (Novick, 1988).

Classroom video clips, by themselves, are unlikely to foster teacher learning without being intentionally integrated into a PD program or course (Blomberg et al., 2014). Along with the purposeful selection of video clips, a central component of designing effective PD materials is determining how to embed the video within the broader curriculum to accomplish identified learning goals. It is essential to situate the video in a framework that supports detailed analysis and interpretation, thereby providing access and opportunities for teacher learning across the totality of the PD experience. Both the video and the activities surrounding the video should be designed to target predetermined learning goals for both the PD curriculum as a whole as well as each individual session (Blomberg et al., 2013).

Many, but not all, video-based mathematics PD programs have teachers engage in specific activities before and after watching the focal video (Borko, et al, 2015; LeFevre, 2004; Santagata, 2009). For example, prior to watching a clip, PD facilitators may ask the teachers to solve and discuss the math problem shown in the video in order to develop content knowledge, motivate teachers to notice particular elements of the content contained within the clip, and attend to specified activities such as a unique solution method or teacher questions that prompt extended student reasoning. After viewing the video, there may be a guided discussion and, perhaps, follow-up activities in which the teachers relate what they have seen on the video to their own classroom practice. The discussion and follow-up activities extend teachers' thinking and analysis by probing more deeply into topics or issues presented within the video.

We label this intentional sequencing of video viewing such that it occurs between designated activities with specified learning goals a "video in the middle" design (Seago et al., 2018). In video-based mathematics PD that incorporates this design feature, video is located in the middle of the learning experience, sandwiched between activities such as mathematical problem-solving and pedagogical reflection. We will describe how we use this sequence in more detail when we discuss the Video in the Middle project that is the focus of this paper and will provide an illustrative vignette to depict how the specific sequence looks in action. Our goal is not to argue that this design feature is new to the field of professional development, but rather to highlight and label it, consider how the design is likely to support teachers' learning, and help inform leaders who facilitate mathematics PD.

Teacher Noticing as a Conceptual Frame

Mathematics teachers come to professional learning situations with varying levels of knowledge, much like the K-12 students who come to their mathematics classrooms. One unique aspect of teachers' knowledge is their "professional vision", which refers to their ability to notice and analyze features of classroom interactions, make connections to broader principles of teaching and learning, and reason about classroom events (Sherin, 2007; van Es & Sherin, 2002). Over the years, diverse conceptions of noticing have emerged in the literature, but in general most discussions of mathematics teacher noticing involve two main processes: (1) Attending to particular events in an instructional setting (i.e., teachers choose where to focus their attention and for how long) and (2) Making sense of events in an instructional setting (i.e., teachers draw on their existing knowledge to interpret what they notice in classrooms) (Sherin et al., 2011). Sherin et al. (2011) argue that these two aspects of noticing are not discrete, but rather interrelated. Teachers attend to events based on their sense-making, and how they interpret classroom interactions influences where they choose to focus their attention.

Teacher education programs that incorporate video foster the development of teachers' noticing skills (Koellner & Jacobs, 2014; Roller 2016; Santagata & Yeh 2013; van Es & Sherin, 2002). As they attend to and make sense of PD focused on cases of instruction, teachers are also likely to consider the implications for their own practice (Koh, 2015). In other words, what teachers notice appears directly relevant to how they elect to carry their learning into their classrooms (Sherin & van Es, 2009). Participants in PD do not all make sense of their experiences in the same way; rather, individuals bring differing knowledge and beliefs about teaching and learning, students, content, and curriculum to bear on what they notice (Erickson, 2011; VanEs, 2011). This individual diversity impacts what they notice, how they engage in the professional development and what they take and use in their own practice. It also has implications for the purposeful design of video-based PD and teacher education (Hatch et al., 2016).

Online Teacher Professional Development

As video technology and online video sharing have become more accessible and widespread, video-based professional learning is well-positioned to leverage the benefits of digital platforms especially during the pandemic (Teräs & Kartoglu, 2017). Online teacher professional development (oTPD) allows mathematics teachers access to professional development resources that may not be available to them locally and can also support those who are reluctant to share ideas in face-to-face settings in becoming more comfortable doing so in digitally mediated interaction (Dede et al., 2009). Online teacher PD is considerably more scalable than comparable face-to-face PD, and in many cases is subject to fewer monetary and logistical constraints for teachers (Killion, 2013). Research to date on online professional development has shown some positive effects for teachers, even compared to face-to-face formats (Chauvot et al., 2020; Nite & Bicer, 2020; O'Dwyer et al., 2010; Telese & Chamblee, 2020). Most research comparing online, and face-to-face versions of PD has found that well-designed online courses utilizing high-quality learning materials intended for individual use can produce learning outcomes that are similar to or better than face-to-face options (Fisher et al., 2010; Fishman et al., 2013).

Fishman (2016) reminds us that oTPD is PD. The professional learning opportunities in an online environment and a face-to-face setting are both determined by the learning design of the program, as different approaches can lead to different learning experiences (Fishman, 2016; Prosser & Trigwell, 1999). Herrington et al. (2010) propose principles of authentic e-learning within a framework based on the theory of situated learning (Lave & Wenger, 1991). Situated learning theory assumes that learning takes place in an authentic context that preserves the complexity of practice —a context that can occur in differing settings such as live, virtual, or video representations of practice (McLellan, 1994). The authentic e-learning principles proposed by Herrington and colleagues focus on authentic context, authentic tasks, access to experts, multiple perspectives, collaboration, reflection, articulation, scaffolding, and assessment. This paper reports on the design and preliminary findings from a project that is adapting face-to-face mathematics PD materials to an asynchronous digital format that utilizes these authentic e-learning principles.

Affordances of Asynchronous Teacher Professional Development

By asynchronous PD, we mean learning activities that happen at different times for different participants; that is, participants are not required to be available at the same time (Dash et al., 2012). Asynchronous PD environments can include social networks, discussion boards, self-paced online courses, resource-sharing sites, and are often transformed or defined by technology (Bates et al., 2016). In recent years, asynchronous, remote opportunities have provided teachers with more and more opportunities to engage in professional learning when high-quality in-person PD is not available or practical (Appana, 2008; Kleiman, 2004; Laferriere et al., 2006; Walker et al., 2008; Wells et al., 2006). While face-to-face professional learning provides many benefits, teachers may struggle to participate due to a number of possible factors such as: the costs of substitute teachers, travel time, scheduling conflicts or a national pandemic (Abbott et al., 2006; Archibald & Gallagher, 2002; Elges et al., 2006; Wentling et al., 2000). Teachers who do not have a school or district peer teaching the same subject or grade level may also struggle to find meaningful, in-person PD opportunities, and for those working in rural or other remote or isolated settings, high-quality in-person PD opportunities may not exist at all (Kleiman, 2004). Even when teachers are able to participate in some face-to-face opportunities, research shows that consistency and coherence is key (Darling-Hammond et al., 2017); asynchronous PD experiences may also be used in conjunction with less frequent face-to-face or synchronous opportunities in a way that provides teachers with a more impactful experience.

While asynchronous teacher PD can pose some challenges for collaboration and interactivity due to their focus on self-directed learning (Alterman & Harsch, 2017), it also offers a unique set of affordances that make it a genuinely attractive option and not merely a fallback alternative when in-person PD is not possible (Meritt, 2016; Pletola et al., 2017. During the Video in the Middle project research study in March 2020, the benefits of this asynchronous PD became more pronounced as the pandemic emerged and teachers found themselves shifting to remote instruction with little time to prepare. In addition to providing meaningful professional learning during times that are convenient or that may not otherwise be available to teachers locally, asynchronous experiences may offer teachers the ability to choose offerings that address their immediate classroom needs, suit their individual learning styles, or allow them to interact with material in a variety of multi-media formats (Docherty & Sandhu, 2006; Garrison & Cleveland-Innes, 2005; National Staff Development Council, 2001; Richardson, 2002; Spicer, 2002; Treacy et al., 2002). For teachers working in remote environments, asynchronous PD can also connect teachers to networks of other professionals and reduce feelings of isolation (DuFour, 2002; National Staff Development Council, 2001).

Asynchronous teacher PD may also foster higher-quality, more reflective dialogue. Text-based discussions in online PD tend to be more exact and organized (Garrison et al., 2001; McCreary, 1990), involve more formal and complex sentences (Sotillo, 2000; Warschauer, 1995) and incorporate critical thinking, reflection, and complex ideas (Davidson-Shivers et al., 2001; Marra et al., 2004). There is also evidence that asynchronous professional learning experiences can support more open and uninhibited dialogue about sensitive subjects since teachers are able to share ideas and questions when they feel ready rather than feeling "on the spot" in a face-to-face environment (Spicer, 2002; Treacy et al., 2002). The ability to work at their own pace and has also been shown in some cases to increase the amount of PD in which teachers are willing to participate (Paskevicius & Bortolin, 2015; Russell et al., 2009).

While asynchronous professional development has grown in popularity in recent years, instructional leaders and PD providers are finding that, in the current pandemic, conducting high-quality, asynchronous teacher PD is not only possible, but more critical than ever. During the pandemic, teachers, coaches, and other PD providers continue to work from home or hybrid settings and juggle a variety of competing priorities while attempting to learn an entirely new way of teaching, flexible, easy-to-access professional learning experiences that teachers can engage with at their convenience are greatly needed (Boaler et al., 2020; Darling-Hammond et al., 2020; Reimers & Schleicher, 2020). The benefits of this asynchronous PD became pronounced as the pandemic emerged during the research study and teachers found themselves shifting to remote instruction with little time to prepare.

The Video in the Middle Project

The goal of the Video in the Middle (VIM): Flexible digital experiences for mathematics teacher education (NSF Award #1720507) project is to design, develop, and research an asynchronous, video-based form of mathematics professional development/teacher education. The VIM project draws upon the *Learning and Teaching Linear Functions: Videocases for Mathematics Professional Development* (NSF; ESI-9731339) video and ancillary resources (e.g., lesson graphs, transcripts, mathematics and video commentaries) to develop a bank of 40 individual two-hour VIM modules grounded in teachers' mathematical knowledge for teaching linear functions, expressions, and equations. These modules will serve as the component ingredients for creating suggested sequences and pathways of multiple VIM modules based on mathematical and pedagogically focused professional learning opportunities. Mathematical learning goals focus on content-related ideas such as conceptualizing and representing slope, distinguishing between and connecting recursive and closed methods and presentations, and exploring the impact of shifting the starting point (y-intercept). Pedagogical goals provide opportunities for managing meaningful mathematical discourse, examining purposeful questions, using and connecting mathematical representations, and establishing goals to focus student learning (NCTM/NCSM, 2020).

The VIM modules are designed to be offered in three asynchronous digital delivery formats: (1) independent, (2) locally facilitated groups, and (3) VIM project-facilitated groups. Each of these formats offers unique affordances for teachers and provides users with both flexibility and choice in their professional learning, as we believe that teachers will appreciate constrained but flexible options. Some teachers may prefer to work independently at their own pace and on their own time schedule; others may prefer to work with colleagues at their school with local facilitation from a coach. Or districts may want to offer their teachers the opportunity to participate with other teachers nationally in a facilitated experience. VIM's final design will offer a variety of suggested pathways depending upon goals, grade levels, and mathematics content, with options to personalize a professional learning plan (depending on one's goals) or swap a particular module with another from the bank of VIM modules.

Video in the Middle Module Design

Each two-hour module places a video clip at the center, or "in the middle," of professional learning as teachers take part in an online experience of mathematical problem solving, video analysis of classroom practice, and pedagogical reflection (Figure 1). The overall structure of this design is consistent across all VIM modules and is intended to support teachers professional learning opportunities around mathematical knowledge for teaching (Ball & Bass, 2002) and teacher noticing of student thinking and teacher-student interactions (VanEs & Sherin, 2002). Each VIM module contains the same set of activities embedded in the Video in the Middle design as described in Figure 1.

FIGURE 1. *Video in the Middle PD activities*

Pre-Video Activities:
1. Introduction: Module Goals (mathematical, pedagogical, instructional)
2. Explore Math Task and Reflect in Journal
3. Padlet Wall: Share Your Work on the Math Task (on a community wall)
4. Consider Other Solutions and Perspectives
5. Explore Math Task and Reflect in Journal
Video Activities:
1. Review the Context of the Lesson (examine where the video clip is situated within the lesson)
2. Watch Video and Reflect in Journal
3. Reflect on the Lesson Graph and Solution Methods Documents
4. Examine Video Transcript and Share Your Thoughts
5. Watch Video Again with Math Educator Annotations
6. Watch Video and Reflect in Journal
7. Reflect on the Lesson Graph and Solution Methods Document
Post-Video Activities:
1. Padlet Wall: Reflect on Your Learning (e.g. "I used to think…. Now I think…") on a community wall.
2. Bridge to Practice: Connecting Your Learning to Classroom Practice
3. Reflect in Your Journal

The underlying VIM design principles are consistent with. the nine principles of authentic e-learning as defined by Herrington et al. (2010). Figure 2 illustrates the nine principles and how each is exemplified within the learning design of the VIM modules.

Research Study

The first two years of the VIM project concentrated on the iterative testing and design of the video-based asynchronous modules and accompanying resources. Year three of the project focused on conducting an experimental randomly controlled trial pilot to study the potential for teacher and student impact. During Spring 2020, the pilot efficacy study was conducted with 67 teachers across the three delivery formats (Independent: 25, Locally facilitated: 25, VIM project-facilitated: 17) to address the following research questions:

1. *What is the impact of teachers' participation in the three delivery formats on teachers' mathematical knowledge for teaching and their teaching practice?*
2. *What is the impact on their students' performance?*

Method

Intervention

All teachers experienced the same sequenced four, two-hour modules for a total of eight hours of professional development. Figure 3 (pgs. 34 - 35) displays the mathematical tasks, video clip description and learning goals for each of the four VIM modules used for the research study.

Participants

Middle and high school mathematics teachers were recruited from across the state of California. For the locally facilitated condition, math coaches/leaders from two school districts with which researchers had existing relationships were recruited. The coaches and leaders then recruited teachers of grade 6-8 math as well as Algebra 1/ Math 1. The math coaches/leaders in each district served as the local facilitators for groups in their districts. For the self-paced/non-facilitated condition and the VIM project-facilitated condition, teachers were recruited from districts across California and randomized into two groups. Where multiple teachers were recruited from the same district, teachers were split between the two groups. For districts where only one teacher was recruited, participants were matched using demographic characteristics of the

FIGURE 2. *The Elements of Authentic e-Learning (Herrington et al., 2010) and Their Application in the VIM Module*

Principles of Authentic e-Learning	Exemplified in the Design of Each VIM Module
Authentic context reflects the way knowledge is used in real life, preserving the complexity.	Unedited video clips of un-staged mathematics classroom interactions, highlighting the relationship between content, teacher, and students.
Authentic tasks have situationally relevant content and offer opportunities for practical implementation.	Teachers examine mathematics tasks within the context of a lesson, view and analyze a video clip of the lesson, and consider implications for their own practice.
Access to expert performances by having the opportunity to observe how experts solve problems as well as learn with and from their colleagues.	Teachers have opportunities to consider a mathematician's perspective on the mathematics task and a mathematics educator's perspective on the video clip, as well as the perspectives of their peers.
Promoting multiple perspectives by sharing different view-points and experiences.	Teachers share their work on the mathematics task with others, consider other solution methods, comment on their peers' work, and receive feedback on their own solution methods.
Collaborative construction of knowledge is characterized by collegial sharing, interaction and collaboration between participants.	Teachers explore a mathematics task and post their work on a community wall for their colleagues to view and comment on.
Reflection offers the opportunity to compare one's thoughts to the ideas of other learners, experts and mentors.	Teachers compare their mathematical work and module reflections to that of their peers, their instructional strategies to those of videotaped teachers, and their analysis to that of mathematicians and mathematics educators.
Articulation is encouraged when participants discuss their growing understanding and publicly present and defend arguments.	Teachers present their solution methods to the mathematical task on a community wall for public presentation to their peers and respond to questions or comments.
Scaffolding and coaching are available when needed.	Each module is scaffolded according to mathematical and pedagogical learning goals. Facilitators in local and project formats read and respond to teachers' journals and community wall posts.
Authentic assessment provides learners with the opportunity to be effective performers with the skills and knowledge they have acquired.	At the end of each module, teachers engage in a "Bridge to Practice" activity designed to provide them with the opportunity to use what they have learned in their own practice.

district (race, free/reduced lunch, and EL status). Of the 68 teachers who began the study, 56 (82%) completed all or nearly all study activities, including all four VIM modules. Table 1 shows the completion percentage for each condition.

Across all conditions, grade levels that participants taught ranged from 6 to 12 (some teachers taught multiple grades). Table 2 shows the breakdown of grade levels taught (some teachers taught multiple grades) and Table 3 shows years of teaching experience.

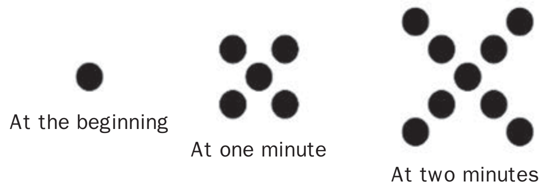
Table 1: Participants' Completion of the Study by Condition

Condition	Began study	Completed study	
		n	%
Self-paced	29	24	83%
Locally facilitated	19	16	84%
VIM project-facilitated	20	16	80%

FIGURE 3. *Four Selected VIM Modules*

VIM 1: James & Danielle: Representing Recursive and Explicit Approaches

Growing Dots

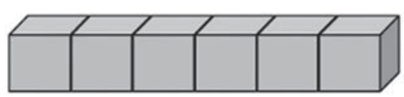


Describe the pattern. Assuming the sequence continues in the same way, how many dots are there in 3 minutes? 100 minutes? *t* minutes?

Learning Goals	Video Clip Description
• Examine, represent, and compare recursive and explicit approaches to solving linear tasks. • Listen to, interpret, and understand differing student approaches to solving the dots task. • Think about goals and instructional decision-making in launching a task.	The teacher asks his 9th grade students to share their solutions and methods for solving growing dots 1. Danielle shares the equation x4+1 and shows the one as the center with a circular growth of 4 dots at each minute. James shares his equation as x + 4 and points to the dot sequence as he shows that 4 is added each time to the previous picture. James says that he didn't count the center because then center is not growing.

VIM 2: Breanna & Cody: Representing Mathematical Thinking

Cubes in a Line



How many faces (face units) are there when two cubes are put together sharing a face? 10 cubes? 100 cubes? How many faces for any number of cubes?

Learning Goals	Video Clip Description
• Examine, represent, and compare the mathematics behind various solution methods. • Listen to, interpret, and understand differing student's mathematical thinking in solving the cubes task. • Think about posing questions in orchestrating a classroom discussion.	This 3rd grade class was given the task of predicting the number of faces for 10 cubes. This segment is a whole class discussion of their predictions based on 2 students' methods. Breanna says you just count down and add 4 more so it is 42. Cody says that you multiply the cubes by 4 and add 2.

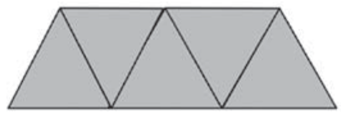
Table continues on next page

FIGURE 3. *Four Selected VIM Modules (continued)*

VIM 3: Lindsey's Question: Connecting Geometry to a Rule

Polygons

If I line up (sharing one side) 100 regular triangles in a row, whay will the perimeter be?



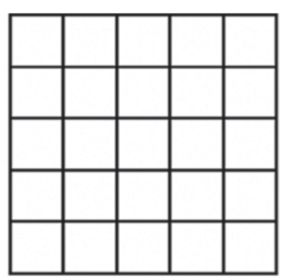
Can you create a rule for finding the perimeter for any number of triangles?

Learning Goals	Video Clip Description
• Make sense of how two different approaches to the general rule for the task connect to its geometry. • Examine how a teacher responds to students' ideas and questions. • Consider how you might purposefully plan your questioning in order to elicit student thinking.	During the 7/8th grade whole class discussion of the triangle problem, Kristen says that the perimeter for any number of triangles would be the number of triangles plus 2. The teacher writes t + 2 = p on the overhead. She asks the class why the rule says we're only adding t + 2 when every time we add a triangle, we are adding 3 edges. Nick responds that two sides get closed off. Chris says that you have the top and bottom and you add two for the ends. Lindsey asks, "Why isn't it plus 4?"

VIM 4: Siri & Tiffany: Using and Connecting Mathematical Representations

Pool Border

Find the number of 1 by 1 tiles required to surround a 5 by 5 pool.



Pool

Find a rule to predict the number of tiles required to surround a square pool of any size. See if you can express that rule as an equation. Be prepared to explain how your equation relates to the pool and border.

Learning Goals	Video Clip Description
• Connect the structure of a visual representation to a mathematical equation • Discuss the role of the teacher in enabling students to communicate and represent their mathematical ideas • Use and connect mathematical representations	After the 8th grade students work in groups on the Pool Border task, the teacher asks Siri and Tiffany's group to share their equation, $n = s4 + 4$, with the class. They explain that if you decompose the border into sides and corners, and group one side and one corner together, you have 4 of them. They share that this is the same thing as adding s + 1 four times, which they share as their second equation.

Table 2: Grade Levels Taught by Study Participants

Grade Level	n
Grade 6	12
Grade 7	25
Grade 8	31
Grade 9	21
Grade 10-12	10

Note: Most teachers taught more than one grade level

Table 3: Study Participants' Years of Teaching Experience

Teaching Experience	n
0-1 years	5
2-5 years	22
6-10 years	11
More than 10 years	30

Measures

In order to answer our research questions, a variety of measures were used to gather impact data on teachers and students. Teacher measures included an online pre-post video and student work analysis, weekly online teacher logs, teacher interviews, and PD embedded pre-post community wall posts and comments. The pre-post student measure was an online quiz aimed at analyzing student's conceptualization of linear functions. Each measure is described in more detail below.

ARTIFACT ANALYSIS

Teachers were given a pre-post online Artifact Analysis measure designed to examine teachers' mathematical knowledge for teaching. The Artifact Analysis is a three-part instrument in which teachers:

1. Solve a mathematical task, predict student solution methods, analyze different representations, and predict student misconceptions.
2. View and answer a series of increasingly specific questions about several short videos of a class discussion centering on students' presentation of their various solution methods.
3. Comment on three pieces of written student work for the same task.

WEEKLY ONLINE LOGS

Online logs, designed to gather information on teachers' instructional practice, were completed weekly by participating teachers. Specifically, the logs documented how teachers reported implementing key content and instructional strategies highlighted in the module learning goals in their classrooms. In addition, fourteen teachers were interviewed individually about their experiences with the VIM modules.

EMBEDDED COMMUNITY WALL RESPONSES

Within the VIM RCT four module experience, two types of community wall pre-post responses were analyzed: (1) VIM 1 and VIM 4 posted mathematical work and teacher comments/questions regarding each other's methods, and (2) VIM 1 and VIM 4 posted reflections from module experience.

STUDENT ONLINE QUIZ

A short, targeted online student quiz was created to assess students' conceptual understanding of linear functions and their ability to use them to solve problems and communicate their reasoning. The pre quiz was completed by 5,070 students and took no longer than half an hour to complete. It was delivered via a Google Form and included three questions with two parts each—short written explanations as well as multiple choice answers.

Due to the COVID-19 pandemic and schools moving to remote instruction after week 6 of the study, we were unable to administer the post student quiz measure or to conduct teacher observations as planned. All other data, the artifact analysis teacher pre-post measure, weekly teacher logs, and community wall responses and reactions, were completed due to the fact that they were collected online. Post teacher interviews were conducted via telephone. For this paper, we will share our early analysis of the teacher log data results, teacher interviews, and community wall mathematics task responses. We are currently in the process of analyzing the pre-post artifact analysis measure and pre-post community wall reflections responses and anticipate having results by spring 2021.

Table 4: Completion Rates of Online Teacher Logs

Condition	Week 1 *n* = 53	Week 2 *n* = 47	Week 3 *n* = 46	Week 4 *n* = 54	Week 5 *n* = 51	Week 6 *n* = 46	Week 7 *n* = 52	Week 8 *n* = 52
Self-paced	86%	83%	59%	79%	76%	69%	72%	72%
Locally facilitated	74%	58%	74%	84%	74%	68%	84%	84%
VIM Project-facilitated	70%	60%	75%	75%	75%	60%	75%	75%

Results

Weekly Online Teacher Logs

Each week, teachers were asked to complete an online teacher log consisting of eight questions focused on mathematical content taught, student interaction structures, and instructional strategies used during that week. Of the 68 participants who completed the study, Table 4 shows the percentage of the 68 participants across the three conditions who completed each log.

Although the response rates remained high for weeks 7 and 8, nearly all teachers responded that they did not teach mathematics for those weeks due to school closures, so responses for those weeks were not included in the analysis. Of the 68 teachers who began the study, 52 completed all four VIMs and indicated in at least four of the first six logs that they taught math that week. (Teachers sometimes missed logs or indicated that they did not teach math that week due to school breaks or other reasons.) These responses were analyzed for similarities and differences in completion rates within and across the three conditions. With a few exceptions, the completion rates across all conditions were fairly consistent. During the first six weeks of the study, the percentage of teachers reporting they taught topics related to linear functions and linearity gradually decreased somewhat (Table 5).

Neither teachers' reported use of VIM instructional strategies (Table 6) nor students' use of related solution strategies (Table 7) changed dramatically over the course of the six weeks. This may be due to several factors:

- Teachers reported teaching less linearity content as the six weeks went on, and some may have felt unsure how (or if) these techniques applied to content not addressed by the VIM modules;
- If teachers' adopted materials were substantially different from the tasks used in the VIM modules, they may have been unsure how to apply these strategies with their materials;
- The study period may have been too short a time for some teachers to become comfortable using new instructional strategies in their classrooms;
- Teachers who did not complete all four VIMs and four of the first six logs were excluded from analysis, so the remaining teachers may represent a group more enthusiastic about reform teaching strategies or trying new methods; it is possible that more teachers in average in this group had encountered these strategies before and were already using them in class. Analysis of teachers' pre/post Artifact Analysis measures will shed light on whether these teachers had higher-than-average MKT before the study.

Table 5: Types of Mathematics Participants Reported Teaching

Type of Mathematics	Week 1 *n* = 47	Week 2 *n* = 42	Week 3 *n* = 38	Week 4 *n* = 50	Week 5 *n* = 46	Week 6 *n* = 44
Linear Functions	55%	48%	45%	50%	41%	32%
Other Linearity Topics	45%	36%	29%	24%	20%	23%
Other Algebra Topics	43%	43%	39%	42%	43%	52%
Other Math Topics	28%	36%	42%	40%	37%	41%

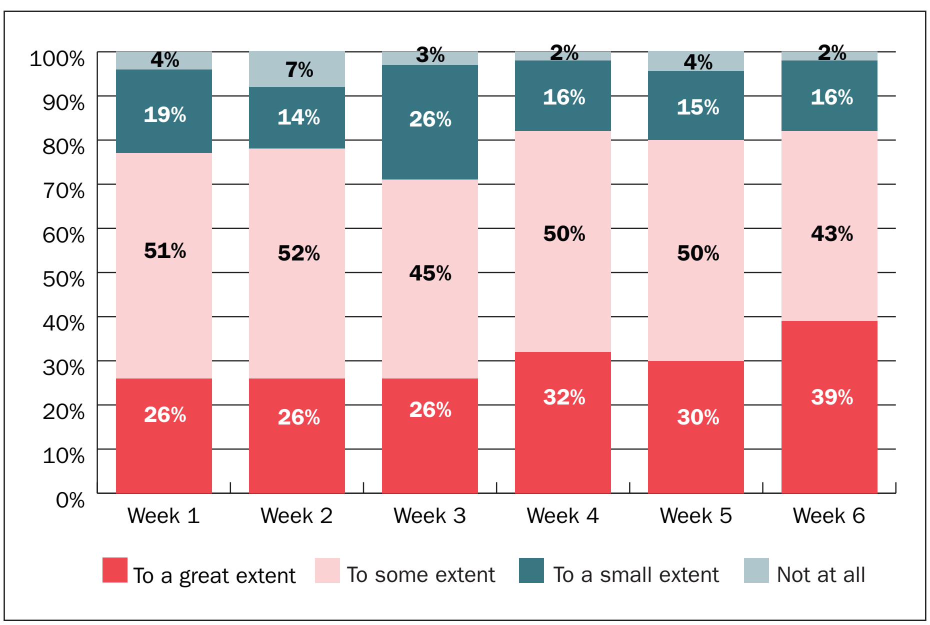
Table 6: VIM Strategies Participants Reported Using

VIM Teacher Strategies	Week 1 *n* = 47	Week 2 *n* = 42	Week 3 *n* = 38	Week 4 *n* = 50	Week 5 *n* = 46	Week 6 *n* = 44
Linking algebra and geometry	74%	48%	58%	52%	48%	64%
Use of color to connect representations	38%	33%	29%	34%	30%	36%
Highlighting multiple solutions	68%	60%	61%	62%	59%	68%
Probing to elicit math ideas	66%	79%	82%	68%	72%	64%
Connecting representations	53%	55%	58%	46%	48%	48%
Other	9%	14%	11%	6%	15%	2%

Table 7: VIM Strategies Teachers Reported Students Using

VIM Student Strategies	Week 1 *n* = 47	Week 2 *n* = 42	Week 3 *n* = 38	Week 4 *n* = 50	Week 5 *n* = 46	Week 6 *n* = 44
Linking algebra and geometry	64%	50%	55%	52%	52%	52%
Use of color to connect representations	28%	29%	32%	28%	22%	23%
Listening to/critiquing others' solutions	53%	71%	55%	62%	70%	59%
Connecting representations	64%	57%	58%	70%	59%	73%
Other	11%	14%	11%	6%	7%	5%

FIGURE 4. *Participants' Responses to the Question, "I can apply VIM ideas with my adopted materials."*



Three Likert-style questions asked teachers to reflect on their teaching experience each week and select one of four answers (not at all, to a small extent, to some extent, to a great extent). Two questions showed increases from week one to week six.

With the question "I am able to apply VIM ideas when working with my district's adopted materials," there was a 13% increase from week one to six in teachers answering, "To a great extent" (Figure 4). There was not much change among teachers who initially answered "To a small extent" or "Not at all" (23% to 18%); this may be because some teachers simply felt that their materials were too different from the tasks presented in the modules to support the use of VIM strategies.

With the second question ("I am able to understand student solution methods that are different than my own"), teachers' responses did not change substantially from week 1 to week 6 (see Figure 5). This may be due to the possible selection bias discussed above, where teachers with higher than average MKT may be overrepresented among those who completed all four VIM modules and at least four out of six weekly logs (those whose weekly logs were included in the analysis). As a result, we may be seeing a ceiling effect in responses to this question.

FIGURE 5. *Participants' Responses to the Question, "I am able to understand student methods different from my own."*

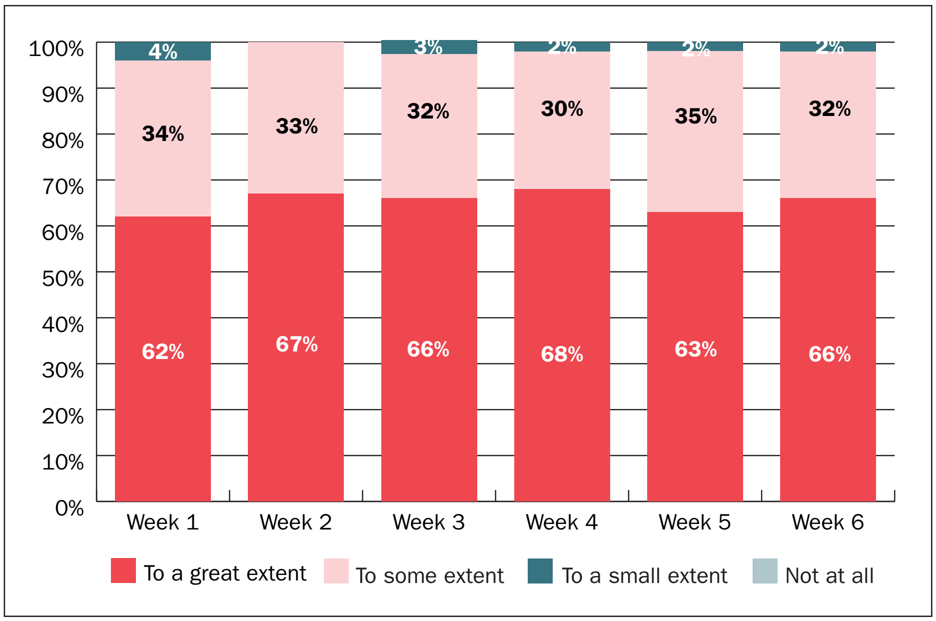
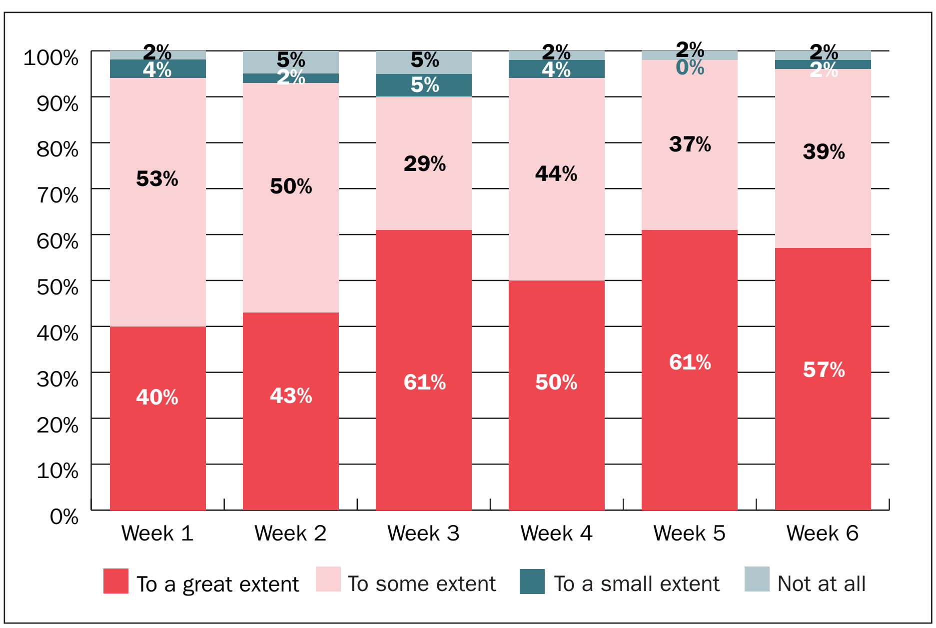


FIGURE 6. *Participants' Responses to the Question, "VIM strategies deepen conceptual knowledge"*



Question three of the teacher log asked teachers if VIM activities helped deepen students' conceptual knowledge of algebraic ideas (Figure 6). There was an 17% increase in teachers responding "To a great extent", with a 21% increase from week 1 to week 5. While teachers reported teaching less linearity content in the later weeks, virtually all were still working on completing VIM modules, so we predict this increase was due mainly to what teachers were experiencing in the PD modules.

Teacher Interviews

Of the 56 teachers who completed the study, nine were randomly selected for interviews in June and July 2020, three from each condition. We also requested interviews with the ten teachers who did not complete the study and received five positive responses.

All teachers interviewed who completed the study expressed that they found the VIM PD modules engaging and useful. Interestingly, interview data did not align with the weekly log data where teachers did not report using VIM strategies more frequently over the course of the study; when asked to highlight specific ways in which the PD had impacted their thinking or practice around teaching linear functions topics, interview subjects mentioned the following more than once:

- Changing questioning strategies and patterns to "focus" student thinking on the learning goal, rather than "funneling" towards a particular strategy or conclusion.
  - The language of focusing and funneling was included in VIM 3 Bridge to Practice activity in which participants examined a chart comparing how two different teachers use the Triangles task in their classroom and facilitated the class discussion by asking questions of students by focusing or funneling (Herbel-Eisenmann & Breyfogle, 2005).
- A greater focus on students' mathematical thinking and reasoning (vs. finding answers)
- Adjusting participation structures and lesson formats to give students more time to work collaboratively
- Desire to use more "open" or visual math tasks, usually thanks either to seeing these tasks used in real classrooms or to feeling more confident in their ability to use them effectively
- Renewed commitment to supporting productive struggle (e.g., letting students struggle with a problem for longer, and asking probing questions rather than giving answers when students are stuck)
- A greater emphasis on multiple representations, including connecting representations through color and probing questions
- Increased openness to multiple ways of seeing and describing linear growth and mathematical structure
- Openness to using manipulatives with older students

When asked to comment on features or elements of the VIM modules that they found most beneficial, the videos, lesson graphs, and community walls were all mentioned by a majority of teachers. Many commented that watching a video of a real classroom helped them better understand what teacher moves described in the PD would look like and how real students might respond. In particular, seeing a video of elementary students working on one of the tasks gave some teachers confidence that their middle school students could approach and benefit from it. Many also expressed that it was helpful to see a variety of ways tasks could be approached or solved, whether in the videos, the solution methods document, or in other participants' work posted on the community walls.

As we hypothesized, teachers in different conditions described different affordances of each. For example, most teachers in the facilitated groups appreciated receiving feedback from a coach in their district or a VIM facilitator, while those in the self-paced group enjoyed the flexibility of being able to complete the modules at their own pace. As one self-paced participant said, "I like this particular experience because I can go at my own pace, and it was still almost like it was facilitated because there were questions that you had to answer."

The benefits of asynchronous, online PD became even more pronounced as the pandemic worsened in March and teachers found themselves shifting to remote instruction with little time to prepare, while also juggling family health concerns and supporting their own children's remote learning. Many expressed gratitude both for the opportunity to complete the PD experience even under shelter-in-place orders as well as the ability to fit their module work around other work and family obligations.

Teacher Community Walls

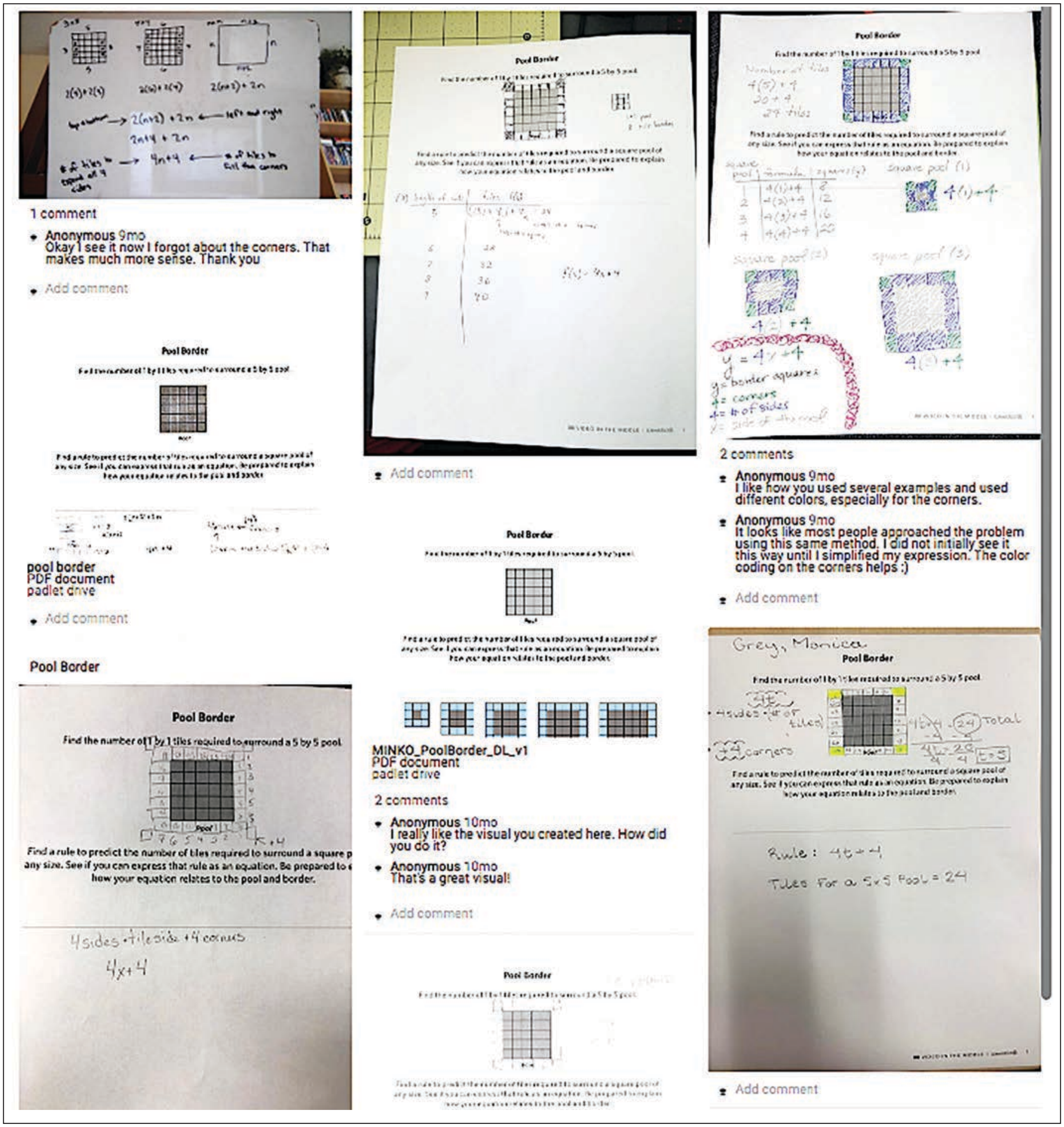
Within each of the four VIM modules, teachers worked on the mathematical task that the students in the video clip engaged with. After solving the problem, they uploaded an image of their work and other teachers (and facilitators in the facilitated conditions) commented or asked questions (Figure 7).

The community mathematics wall participation was high among all three conditions. In the locally facilitated condition, 80% of participants posted their mathematical work in the first VIM module and 95% posted their work in the final VIM module. In the self-paced group, 88% of the participants posted their mathematical work for the first module and 100% posted in the final module. In the VIM project facilitated group, 100% of the participants posted their work in both the first module and last modules. The VIM project facilitated group had the least amount of pre non-facilitator comments, but a similar number of comments to the other two conditions (Table 8).

The most notable pre-post results emerged in the analysis of the visual versus numerical methods used by teachers. Specifically, by condition:

- *Locally facilitated:* Visual methods from 3% of the total methods posted in module 1 to 89% in module 4; numerical methods from 70% of the total methods posted in module 1 to 11% in module 4

FIGURE 7. *VIM Community Mathematics Task Wall*



- *VIM project facilitated:* Visual methods from 6% of the total methods posted in module 1 to 94% in module 4; numerical methods from 82% of the total methods posted in module 1 to 6% in module 4
- *Self-paced:* visual methods from 18% of the total methods posted in module 1 to 85% in module 4; numerical methods from 82% of the total methods posted in module 1 to 6% in module 4

Table 8: Participants' Posts, Comments, and Methods in Module 1 and 4

Condition	Module 1				Module 4			
	Posts & Comments		Methods		Posts & Comments		Methods	
	Posts	Comments	Visual	Numerical	Posts	Comments	Visual	Numerical
Locally Facilitated *Mod 1: 25* *Mod 4: 21*	20	18	6	14	20	16	17	2
VIM Project-Facilitated *Mod 1: 17* *Mod 4: 16*	17	Part: 12 Fac: 14	1	16	16	Part: 16 Fac: 7	14	2
Self-paced *Mod 1: 25* *Mod 4: 20*	22	26	4	18	20	14	17	1

The large majority of methods across all conditions in the VIM 1 community mathematics task wall responses were numerical, while the large majority of methods across all conditions in VIM 4 were visual. We hypothesize that this result could be related to a number of things:

- The VIM learning goals highlighted multiple methods with an emphasis on visual methods.
- The solution methods resource for each VIM highlights visual methods and the links between numeric and visual representations.
- The participants had repeated exposure to the various student visual methods in the four VIM module video clips.
- The participants had repeated exposure to each other's methods with each of the four VIMs.

In addition, these results map onto the **teacher log** results showing an increase of 14% from week 1 to week 6: "I am able to understand student solution methods that are different than my own". These results also correspond to the **interview data**, in which teachers indicated:

- A greater emphasis on multiple representations, including connecting representations through color and probing questions
- Increased openness to multiple ways of seeing and describing linear growth and mathematical structure

Analysis of Community Wall Comments

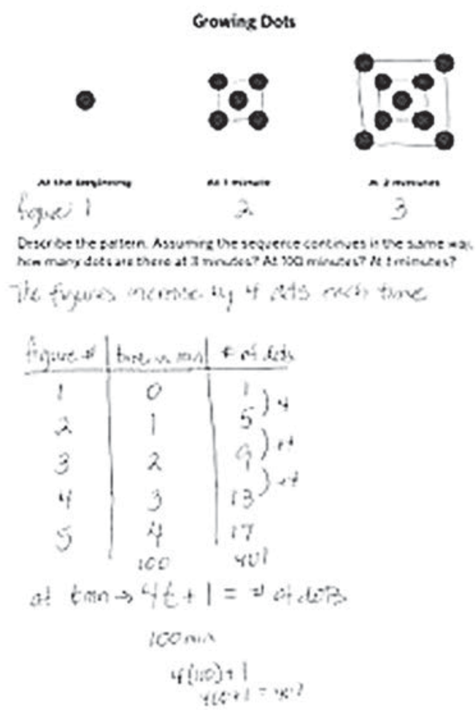
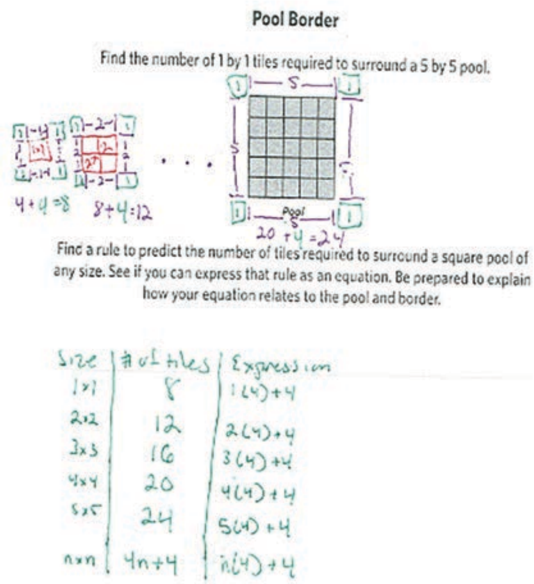
In addition to analyzing the comments quantitatively, we examined the comments qualitatively. In general, comments in VIM 1 were focused on recognizing, agreeing with, and appreciating the tabular approaches. A couple of comments were focused on providing advice/teaching tips. Comments in VIM 4 included more appreciation for a variety of approaches, recognizing the value of using color, and connecting to/learning from other participants' work. Table 9 shows differences in each condition from Module 1 to Module 4.

Discussion

The preliminary results on teacher impact show some consistent findings across different data sources—weekly logs, post PD interviews and pre-post community mathematics task walls. Teachers appeared to have learned to appreciate and use visual methods for solving problems, including using color to distinguish and highlight the relationship between numeric, algebraic, and geometric models. In addition, teachers engaged with and interacted with each other by examining, commenting on, and questioning each other's mathematical work.

A surprising preliminary result was the fact that there were no substantial differences across the three conditions regarding teacher engagement and interaction on the community mathematics task wall. We hypothesized that the

Table 9: Differences in Community Wall Comments from Module 1 to Module 4 by Condition

Group	Module 1	Module 4
Locally Facilitated	• Mostly appreciated table and chart solution methods. • The work that showed an error generated the most comments (4). • One comment was different in nature: *"I like how you connected your dots. It makes it easier to see the pattern of adding four."* 	• Identified with/appreciated others' approaches. • Appreciated others' explanations. • Appreciated visuals and use of color: "Your rule matches the pattern I found in one of my tables. Things like that make me go "Ah hah!". 

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facilitated group would be more engaged and post more comments in response to their colleagues' methods. This did not turn out to be the case, as teachers across all three conditions commented in similar numbers and shifted from numeric to visual methods from pre to post.

Implications for Mathematics Education Leaders

Mathematics leaders are often placed in the position of creating their own PD materials more or less from scratch or pulled together from many different sources. Because of time and resource limitations, this often results in all teachers receiving "one-size-fits-all" PD experiences that are not necessarily responsive to their needs and interests.

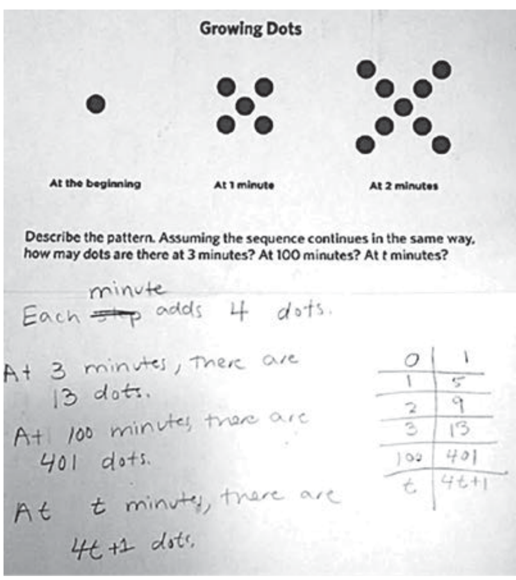
The VIM project aims to support mathematics education leaders by disseminating the VIM modules and resources as open education resources to mathematics leaders in a variety of flexible formats and bundlings, beginning Spring/Summer 2021. We plan to advertise the release of these modules on WestEd's website (www.wested.org) as well as through mathematics education and mathematics leadership professional organizations.

Using the VIM modules, leaders can provide the teachers they support with high-quality PD experiences that can be completed asynchronously, allowing teachers to schedule their PD work around their other responsibilities. As we saw in our research study, this flexibility may be particularly

Table 9: Differences in Community Wall Comments from Module 1 to Module 4 by Condition (continued)

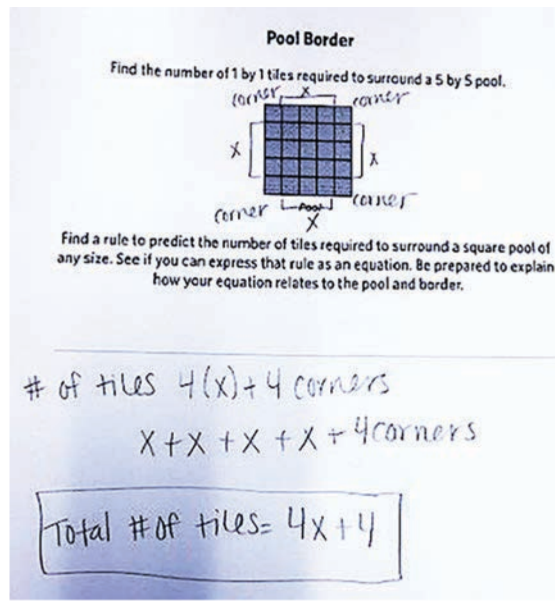
<table>
<tr><th>Group</th><th>Module 1</th><th>Module 4</th></tr>
<tr><td>VIM Project-Facilitated</td><td>

- Facilitators made 14 comments, Participants made 12 comments
- A couple of teachers focused on learning from looking at someone's example:
"I like seeing others do it so I can relate my answer to theirs."
"Your demonstration was very neat and clear. I had to go back and fix mine after observing yours."
- There were a few "seeking to understand" types of comments:
"It's unclear what n or t mean since it's not stated on the paper, but the solution is valid."
- There was one comment that talked about having learned from looking at someone else's example:
"Your response was the first one I saw. When I saw your (0,1) ordered pair, I realized I did it wrong…"



</td><td>

- Several focused on the value of the visuals—marking to show the growth:
"I like how you separate the sides and the corners."
"I like the x's to help students see why there is a plus 4."
- Appreciating different approaches:
"I love it when someone does it different than me. Such a good learning experience."
- Connecting to and learning from others:
"I notice we had the same equations; however, we interpreted the x and corners are different in our drawings."



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</table>

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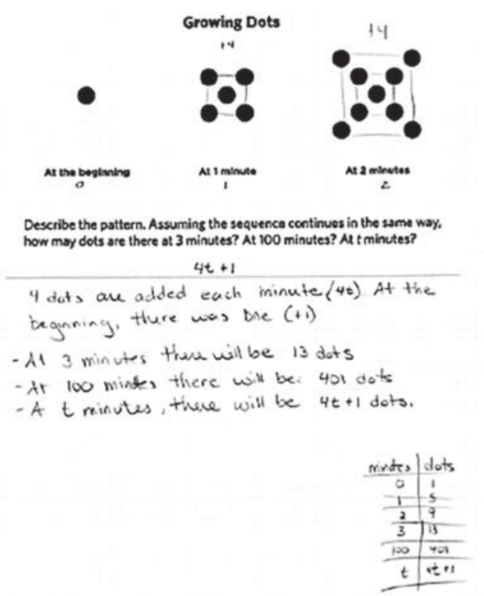
welcome as staff continue to work from home and juggle many competing priorities. In addition, sequence recommendations ("pathways") and sample facilitation guides will be shared in an attempt to support math leaders in meeting teachers' needs. Teachers have different professional development needs and interests due to a variety of factors (Chval et al., 2008; Desimone, 2009; Bautista & Ortega-Ruíz, 2015; Matteson et al., 2013); because the modules address a range of mathematical and pedagogical topics, leaders will be able to select modules that align with district or department priorities, or let teachers choose the modules or bundles that most interest them. The option to deliver the modules in either a self-paced or facilitated format will provide leaders with additional flexibility; depending on district goals, resources, and teacher needs and preferences, they may choose to offer a

Table 9: Differences in Community Wall Comments from Module 1 to Module 4 by Condition (continued)

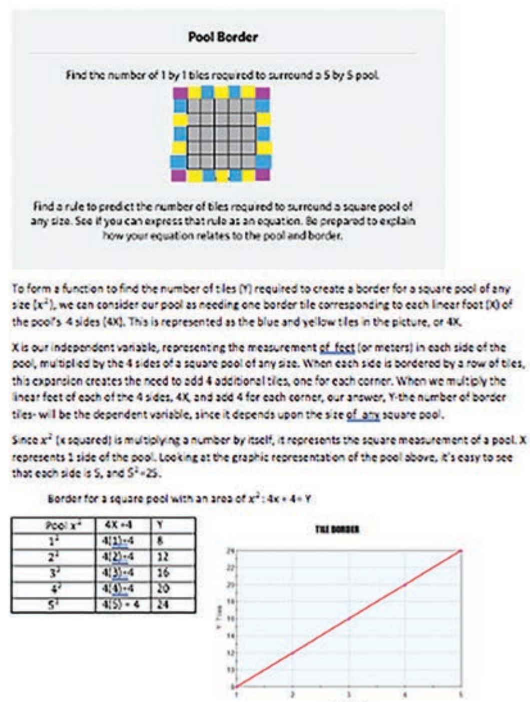
<table>
<tr><th>Group</th><th>Module 1</th><th>Module 4</th></tr>
<tr><td>Self-Paced</td><td>

- Most of the comments (9) focused on appreciating tables:
"I like your table—easy to follow, showing a pattern."
- Others provided advice/teaching tips:
"How would you connect your "+4" pattern to your "4t" for your students?"
- A couple of teachers commented on how someone saw it visually:
"It's interesting how you saw the +4 as progressively larger squares."



</td><td>

- Many teachers appreciated visuals and use of color:
"The color coding on the corners helps." "I like the visual you provided and the color-coded keys."
- One piece of work generated comments reflecting two different perspectives:
"I like the way you used colors to identify the parts of your rule. Visually clarifying."
"I find the different colors distracting. I can see the four corners being a different color."



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</table>

facilitated experience where teachers engage in the same modules or pathways, or to implement a non-facilitated option, either where a group completes the same modules or pathways or individual teachers select which modules to work on.

Finally, the asynchronous, online nature of the VIM modules makes them highly scalable; unlike many face-to-face and synchronous online PD options, math leaders will not need to limit participation due to space or cost concerns, a welcome feature as many LEAs must now balance shrinking budgets. At the same time, community walls still allow for interaction and collaboration among teachers working on the same modules or pathways. PD looks differently during the pandemic and the flexibility of the VIM modules may be a good fit for PD leaders at this moment in time. ✪

References

Abbott, M., Greenwood, C. R., Buzhardt, J., & Tapia, Y. (2006). Using technology-based teacher support tools to scale up the classwide peer-tutoring program. *Reading and Writing Quarterly, 22*(1), 47-64.

Alterman, R., & Harsch, K. (2017). A more reflective form of joint problem solving. *International Journal of Computer-Supported Collaborative Learning, 12*(1), 9–33.

Appana, S. (2008). A review of benefits and limitations of online learning in the context of the student, the instructor, and the tenured faculty. *International Journal on E-Learning, 7*(1), 5-22.

Archibald, S., & Gallagher, H. A. (2002, May 31). A case study of professional development expenditures at a restructured high school. Education Policy Analysis Archives, 10(29). Retrieved from http://epaa.asu.edu/epaa/v10n29.html

Ball, D.L. and Bass, H. (2002). Toward a practice-based theory of mathematical knowledge for teaching. In: B. Davis and E. Simmt, eds. *Proceedings of the 2001 Annual Meeting of the Canadian Mathematics Education Study Group*. Edmonton, AB: CMESG/GCEDM, 3-14.

Bates, M.S., Phalen, L., and Moran, C. (2016). Online professional development: A primer. *Phi Delta Kappan, 97*(5), 70-73.

Bautista, A. & Ortega-Ruíz, R. (2015). Teacher professional development: International perspectives and approaches. *Psychology, Society and Education, 7*(3), 240-251.

Blomberg, G., Renkl, A., Sherin, M. G., Borko, H., and Seidel, T. (2013). Five research-based heuristics for using video in pre-service teacher education. *Journal for Educational Research Online, 5*(1), 90–114.

Boaler, J., Lamar, T., Langer-Osuna, J., Suurtamm, C. (2020). *We're in this together: Supporting high-quality math teaching in uncertain times.* Knowledgehook.

Borko, H., Jacobs, J., Koellner, K. & Swackhamer, L. (2015). *Mathematics professional development: Improving teaching using the Problem-Solving Cycle and Leadership Preparation models.* Columbia University, NY: Teachers College Press.

Borko, H., Koellner, K., Jacobs, J., & Seago, N. (2011). Using video representations of teaching in practice-based professional development programs. *ZDM, 43*(1), 175–187. https://doi.org/10.1007/s11858-010-0302-5

Brophy, J. (2004). *Using video in teacher education: Advances in research on teaching* (Vol. 10). London, UK: Elsevier

Chauvot, J., Pape, S.J., Prosser, S.K., & Hicks, K. (2020). Online mathematics teacher education: Examples from professional learning programs for inservice teachers. In *Handbook of Research on Online Pedagogical Models for Mathematics Teacher Education.* https://www.igi-global.com/chapter/online-mathematics-teacher-education/243496

Chval, K., Abell, S., Pareja, E., Musikul, K., & Ritzka, G. (2008). Science and mathematics teachers' experiences, needs, and expectations regarding professional development. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(1), 31-43

Cullen, R. (1991). Video in teacher training: the use of local materials. *ELT Journal, 45*(1), 33-42.

Darling-Hammond, L., Schachner, A., & Edgarton, A.K. (2020). *Restarting and reinventing school: Learning in the time of COVID and beyond.* Palo Alto. CA: Learning Policy Institute.

Darling-Hammond, L., Hyler, M., Gardner, M., & Gibson, D. (2017). *Effective professional development.* Palo Alto, CA: Learning Policy Institute.

Dash, S., Magidin De Kramer, R., O'Dwyer, L., Masters, J., & Russell, M. (2012). Impact of online professional development on teacher quality and student achievement in fifth grade mathematics. *Journal of Research on Technology in Education, 45*(1), 1–26.

Davidson-Shivers, G. V., Muilenburg, L. Y., & Tanner, E. J. (2001). How do students participate in synchronous and asynchronous online discussions? *Journal of Educational Computing Research, 25*(4), 351-366.

Dede, C., Jass Ketelhut, D., Whitehouse, P., Breit, L., & McCloskey, E. M. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education, 60*(1), 8–19.

Desimone, L.A. (2009). Improving impact studies of teachers' professional development: toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199.

Docherty, A., & Sandhu, H. (2006). Student-perceived barriers and facilitators to e-learning in continuing professional development in primary care. *Education for Primary Care, 17*, 343–353.

Erickson, F. (2011). On noticing teacher noticing. In M.G. Sherin, V.R. Jacobs & R.A. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (17-34). New York and London: Routledge.

Elges, P., Righettini, M., & Combs, M. (2006). Professional development and recursive e-learning. *Computers in the Schools, 23*(1), 45-57.

Fisher, J.B., Schumaker, J.B., Culbertson, J. & Deshler, D.D. (2010). Effects of a computerized professional development program on teacher and student outcomes. *Journal of Teacher Education, 61*(4), 302-312.

Fishman, B. (2016). Possible futures for online teacher professional development. In Dede, C., Eisenkraft, A., Frumin, K., Hartley, A. (Eds.), Teacher learning in the digital age: Online professional development in STEM education (pp. 13–30). Cambridge, MA: Harvard Education Press.

Fishman, B., Konstantopoulos, S., Kubitskey, B.W., Vath, R., Park, G., Johnson, H., and Edelson, D.C. (2013). Comparing the impact of online and face-to-face professional development in the context of curriculum implementation. *Journal of Teacher Education, 64*(5), 426–438.

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education, 15*(1), 7-23.

Garrison, R.D., & Cleveland-Innes, M. (2005). Facilitating cognitive presence in online learning: Interaction is not enough. *American Journal of Distance Education, 19*(3), 133–148.

Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational Research Review, 16*, 41-67.

Hatch, T., Shuttleworth, J., Jaffee, A. T., & Marri, A. (2016). Videos, pairs, and peers: What connects theory and practice in teacher education? *Teaching and Teacher Education, 59*, 274-284.

Harford, J., & MacRuairc, G. (2008). Engaging student teachers in meaningful reflective practice. *Teaching and Teacher Education, 24*(7), 1884-1892.

Herbel-Eisenmann, B. A., & Breyfogle, L.M. (2005). Questioning our patterns of questioning. *Mathematics Teaching in the Middle School, 10*(9), 484-489.

Herrington, J., Reeves, T., & Oliver, R. (2010). *A guide to authentic e-learning.* London: Routledge.

Killion, J. (2013). *Meet the promise of content standards: Tapping technology to enhance professional learning.* Oxford, OH: Learning Forward.

Koellner, K., & Jacobs, J. (2014). Distinguishing models of professional development: The case of an adaptive model's impact on teachers' knowledge, instruction, and student achievement. *Journal of Teacher Education, 66*(1), 51-67.

Koh, K. (2015). The use of video technology in pre-service teacher education and in-service teacher professional development. In *Cases of mathematics professional development in East Asian countries*, 229-247. Singapore: Springer.

Korthagen, F. A., Kessels, J., Koster, B., Lagerwerf, B., & Wubbels, T. (2001). *Linking theory and practice: The pedagogy of realistic teacher education.* Mahwah, NY: Lawrence Erlbaum Associates.

Kleiman, G. M. (2004, July). Meeting the need for high quality teachers: E-learning solutions. Paper commissioned for the U.S. Department of Education National Technology Plan and the U.S. Department of Education Secretary's Leadership Summit on e-Learning, Orlando, FL.

Laferriere, T., Lamon, M., & Chan, C. K. K. (2006). Emerging e-trends and models in teacher education and professional development. *Teaching Education, 17*(1), 75-90.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation.* Cambridge: Cambridge University Press.

LeFevre, D.M. (2004). Designing for teacher learning: Video-based curriculum design. In J. Brophy (Ed.), *Using Video in Teacher Education: Advances in Research on Teaching, Vo. 10.* London: Elsevier, 235-258.

Major, L., & Watson, S. (2018). Using video to support in-service teacher professional development: the state of the field, limitations and possibilities. *Technology, Pedagogy and Education, 27*(1), 49-68.

Marra, R. M., Moore, J. L., & Klimczak, A. K. (2004). Content analysis of online discussion forums: A comparative analysis of protocols. *Educational Technology Research and Development, 52*(2), 23-40.

Matteson, S., Zientek, L. R., & Ozel, S. (2013). Identifying What InService Teachers Want in Professional Development Experiences. *Teacher Education and Practice, 26*(3), 569-580.

McCreary, E. K. (1990). Three behavioral models for computer-mediated communication. In L. M. Harasim (Ed.), *Online Education: Perspectives on a New Environment* (pp. 117-130). New York: Praeger.

McLellan, H. (1994). Situated learning: Continuing the conversation. *Educational Technology, 34*(10), 7-8.

Merritt, E. G. (2016). Time for teacher learning, planning critical for school reform: Students aren't the only ones who need more time to learn; teachers also need more and better time for learning and for planning. Phi Delta Kappan, 98(4), 31–36.

National Staff Development Council. (2001). *E-learning for educators: Implementing the standards for staff development.* Oxford, OH.

NCTM/NCSM (2020). Moving forward: Mathematics Learning in the Era of COVID-19. National Council of Teachers of Mathematics/ National Council of Supervisors of Mathematics.

Nite, S.B., & Bicer, A. (2020). Online mathematics teacher professional development. In *Handbook of Research on Online Pedagogical Models for Mathematics Teacher Education.* https://www.igi-global.com/chapter/online-mathematics-teacher-professional-development/243507

Novick, L. R. (1988). Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*(3), 510.

O'Dwyer, L. M., Masters, J., Dash, S., De Kramer, R. M., Humez, A., & Russell, M. (2010). E-Learning for educators: Effects of on-line professional development on teachers and their students. Chestnut Hill, MA: Technology and Assessment Study Collaborative.

Peltola, P., Haynes, E., Clymer, L., McMillan, A., & Williams, H. (2017). Opportunities for teacher professional development in Oklahoma rural and nonrural schools (REL 2017–273). Department of Education, Institute of Education Sciences, National Center for education evaluation and regional assistance, regional educational Laboratory southwest.

Prosser, M., & Trigwell, K. (1999). *Understanding learning and teaching: The experience in higher education.* Philadelphia: The Society for Research into Higher Education & Open University Press.

Reimers, F.M. & Schleicher, A.S. (2020). *A framework to guide an education response to the COVID-19 pandemic of 2020.* Paris, France: OECD.

Rich, P. J., & Hannafin, M. (2009). Video annotation tools technologies to scaffold, structure, and transform teacher reflection. *Journal of Teacher Education, 60(*1), 52-67.

Richardson, J. (2002). E-learning potential: Online staff development has great possibilities – and pitfalls. In A. Thorson (Ed.), *By your own design: A teacher's professional learning guide* (pp. 12–13). Columbus, OH: Eisenhower National Clearinghouse for Mathematics and Science Education.

Roller, S.A. (2016). What they notice in video: A study of prospective secondary teachers learning to teach. *Journal of Mathematics Teacher Education, 19*, 477-498.

Rosaen, C. L., Lundeberg, M., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing noticing: How does investigation of video records change how teachers reflect on their experiences? *Journal of Teacher Education, 59*(4), 347-360.

Santagata, R. (2009). Designing video-based professional development for mathematics teachers in low-performing schools. *Journal of Teacher Education, 60*(1), 38-51.

Santagata, R., & Yeh, C. (2014). Learning to teach mathematics and to analyze teaching effectiveness: evidence from a video-and practice-based approach. *Journal of Mathematics Teacher Education, 17*(6), 491-514.

Seago, N., Koellner, K. Jacobs, J. (2018). Video in the middle: Purposeful design of video-based mathematics professional development. *Contemporary Issues in Technology and Teacher Education, 18*(1).

Sherin, M. (2007). The development of teachers' professional vision. In R. Goldman, R. Pea, B. Barron, & S. Derry, (Eds), Video research in the learning sciences. New York: Routledge, pp. 383-395.

Sherin, M.G., Jacobs, V.R., & Philipp, R.A. (2011). Mathematics teacher noticing: Seeing through teachers' eyes. New York, NY: Routledge.

Sherin, M.G. & van Es, E.A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education, 60*, 20-37.

Sotillo, S. M. (2000). Discourse functions and syntactic complexity in synchronous and asynchronous communication. *Language Learning & Technology, 4*(1), 82–119.

Spicer, J. (2002). Even better than face-to-face? In A. Thorson (Ed.), *By your own design: A teacher's professional learning guide* (pp. 32–33). Columbus, OH: Eisenhower National Clearinghouse for Mathematics and Science Education.

Telese, J., & Chamblee, G. (2020). Assessing program outcomes of an M.Ed. curriculum and instruction program: A comparison of face-to-face to completely online deliverables. In *Handbook of Research on Online Pedagogical Models for Mathematics Teacher Education* (pp. 22–40). https://scholarworks.utrgv.edu/cgi/viewcontent.cgi?article=1036&context=tl_fac

Teräs, H. and Kartoglu, U. (2017). A grounded theory of professional learning in an authentic online professional development program. *International Review of Research in Open and Distributed Learning, 18*(7).

Treacy, B., Kleiman, G., & Peterson, K. (2002). Successful online professional development. *Leading & Learning with Technology, 30*(1), 42–47.

van Es, E.A. (2011). A framework for learning to notice student thinking. In M.G. Sherin, V.R. Jacobs, & R.A. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 134-168). New York, NY: Routledge.

van Es, E.A., & Sherin, M.G. (2002). Learning to notice: Scaffolding new teachers' interpretation of classroom interactions. *Journal of Technology and Teacher Education, 10*, 571-596.

Walker, D. A., Downey, P. M., & Sorensen, C. K. (2008). E-learning modules for teacher development: Project REAL. *Techtrends, 52*(5), 59-62.

Wells, J., Lewis, L., & Greene, B. (2006). Internet access in U.S. public schools and classrooms: 1994-2005 (NCES 2007-020). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Wentling, T. L., Waight, C., Gallaher, J., La Fleur, J., Wang, C., & Kanfer, A. (2000). *E-learning: A review of literature.* Champaign: University of Illinois, Knowledge and Learning Systems Group.

An Interdisciplinary Coaching Approach to Data-Based Individualization: A Year-Long Partnership Between Mathematics Teachers and Special Education Researchers

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Abstract

This article describes a year-long partnership between a group of general education mathematics teachers and their special education researcher-coach counterparts, an experience we call interdisciplinary coaching. The purpose of this work was aimed at supporting teachers in adopting and implementing an evidence-based instructional practice intended to address the needs of students experiencing mathematics difficulty, including students with disabilities. Findings from this investigation indicate teachers had high rates of satisfaction with the coaching model and that, by some specific measures, this model demonstrates promise for improving teachers' assessment practice within a data-based individualization framework. We describe the unique tensions and affordances that arose from this type of partnership and share recommendations for how others might engage in interdisciplinary coaching work.

Introduction

More than ever, general education mathematics teachers are being tasked with supporting a range of students, including students experiencing mathematics difficulty or those with disabilities.[1] Most students with disabilities receive the majority of their instruction in the general education setting (Office of Special Education Programs, 2017), yet, general education mathematics teachers consistently report feeling unprepared to instructionally support these students (e.g., DeSimone & Parmar, 2006; Mackey 2014). One reason teachers might feel unprepared is because science, technology,

[1] We use the phrase students experiencing mathematics difficulty to include any student that may not be learning as expected within the general education classroom, including students with disabilities. In contrast, the phrase students with disabilities indicates only those students who have been labeled with one or more of the 13 disability categories as defined by the Individuals with Disabilities Education Act (2004). We intentionally use both phrases throughout this article.

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and mathematics teachers receive fewer hours of professional learning about supporting students with disabilities than other teachers (Li et al., 2015). As inclusive learning environments become the norm, professional learning opportunities to support general education teachers in addressing the needs of students experiencing mathematics difficulty is increasingly important (e.g., McLeskey & Waldron, 2002).

In addition to the need for high-quality professional learning opportunities, ongoing instructional coaching (Knight, 2007) is one catalyst for lasting instructional change (Bush, 1984) and has been demonstrated as beneficial for mathematics teachers (e.g., Neuberger, 2012). Historically, the instructional coaching relationship has existed between individuals with mathematics content expertise and mathematics teachers (e.g., Obara, 2010). This relational model is reflected in other disciplines, including when special education teachers have professional learning opportunities in mathematics (e.g., Gersten & Kelly, 1992). That is, coaches and teachers typically come from the same disciplinary background. While there is some evidence that special education teachers have received instructional support from mathematics instructional coaches (e.g., Louie et al., 2008), those instances are rare. Professional learning that crosses disciplinary boundaries typically involves engaging both general and special education teachers in a common professional development session (e.g., Bryant et al., 2001), but not necessarily in a coaching relationship.

One factor that may result in a reluctance to cross disciplinary boundaries might relate to the well-known theoretical divides between the fields of special education and mathematics education (van Garderen et al., 2009; Lambert & Tan, 2017). Despite these differences, fostering interdisciplinary collaborations has the potential to lead to improved access to and inclusion in the general education curriculum, particularly for students experiencing mathematics difficulty (e.g., Brusca-Vega et al., 2014). In order for interdisciplinary collaborations to be successful there must be sufficient time for the collaborating educators to share experiences, expertise, develop a shared vision, and move beyond simply learning about instructional approaches but towards designing instruction together (Bryant et al., 2001; van Garderen et al., 2012). Given the benefits of interdisciplinary collaborations, as well as the guidance for how to maximize such partnerships, interdisciplinary coaching might be an underutilized resource to support general education teachers in working with students with disabilities in the general education classroom.

While no formal definition of interdisciplinary coaching exists, in this article we draw on literature about interdisciplinarity (e.g., Collin, 2009) and define interdisciplinary coaching as a coaching relationship that consists of people with differing disciplinary expertise, working towards a common goal by integrating elements representative of their distinct disciplines. It has been well documented in the extant literature that discipline-specific knowledge related to mathematics instruction (Ball et al., 2008) and instructionally supporting students with disabilities (Simonsen et al., 2010) is not only different, but often times, positioned as disparate (e.g., Zigmond & Kloo, 2011). However, interdisciplinarity is increasingly recognized as a viable, and even necessary, approach to addressing and solving complex problems (Spelt et al., 2009), one of which surely includes the teaching and learning of mathematics.

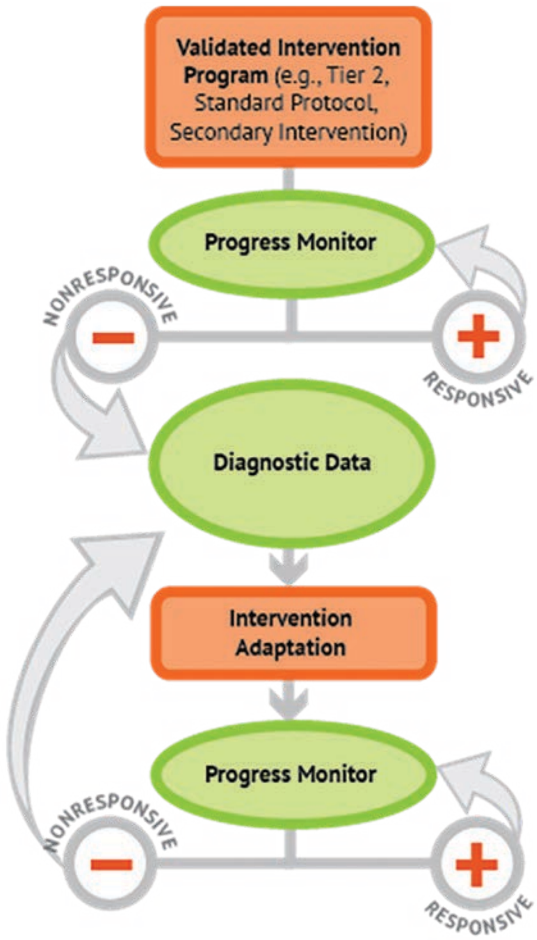
The purpose of this article is to describe an interdisciplinary coaching model that was used to support a group of general education mathematics teachers and special education researcher-coaches throughout a year-long partnership. In the following sections we situate this topic within the coaching and interdisciplinarity literatures, describe the methods used, share findings that demonstrate teachers' overall satisfaction with the coaching experience, and highlight some specific data that suggest preliminary model efficacy. Finally, we unpack some unique tensions and affordances that arose as a result of the interdisciplinary nature of this partnership. We share some reflections and lessons learned from this year-long collaboration, as well as some recommendations for how others might take up the work of interdisciplinary coaching.

Literature Review

Coaching

Research demonstrates that coaching can lead to improved teaching and student learning (Kraft et al., 2018). Coaching done well can dramatically improve performance, while coaching done poorly can be ineffective, wasteful, and sometimes even destructive (Knight et al., 2015). This would imply that a focus on differing approaches to coaching is an important area of research. While the benefits of providing coaching to in-service teachers are clear, we speculate that the coaching dynamic could be enhanced by introducing the perspectives and expertise of other related disciplines.

FIGURE 1.
Data-Base Individualization Framework (NCII, 2013)



Interdisciplinarity

Within mathematics education research that is focused on K–12 learning environments, interdisciplinarity is often framed in relationship to STEM education (e.g., Maass et al., 2019), while work about special education and students with disabilities is limited to investigations of co-teaching (e.g., Rexroat-Frazier & Chamberlin, 2019). In these instances, different disciplinary expertise is often acknowledged, but not leveraged to benefit either teachers or students. The current study attempted to move beyond acknowledgement and knit together the unique disciplinary expertise of the general education mathematics teachers and their special education researcher-coach counterparts.

Interdisciplinary Coaching

Combining the extant literatures, interdisciplinary coaching seems to leverage the strengths of ongoing support for in-service teachers in addition to using the expertise of all involved. Despite the potential benefits of this approach to coaching, interdisciplinary coaching is not, to our knowledge, a construct that has been studied to date. In the following sections, we describe the coaching partnerships that occurred across one school year between general education mathematics teachers and special education researcher-coaches. At no time during the larger study did we name this partnership as *interdisciplinary coaching*. It was only after the experience that we reflected on the distinct tensions and affordances that arose from our disciplinary differences and considered that our experience was something beyond *coaching*.

Methodology

As part of a multi-year, federally-funded project, research teams at three universities partnered with schools to support middle grade general and special education teachers to implement data-based individualization (DBI; see Powell et al., 2021, for an overview of the larger project).

Data-Based Individualization

To understand the work we were inviting teachers to do, the following section describes the research base for DBI and briefly articulates the core tenants of the practice. DBI is a systematic process of analyzing student data to inform instruction. DBI was originally developed in the 1970s (Deno & Mirkin, 1977) but has since been further refined (National Center on Intensive Intervention [NCII], 2013). The DBI process (see Figure 1) is designed to support students who are not learning as expected in the general education curriculum. When students are not learning as expected, most teachers naturally engage in problem solving to improve instruction. The DBI process builds on teachers' proclivity to problem solve by providing a structure to the problem-solving process that integrates the use of student data.

The DBI components of assessment and instruction are carried out using five steps. *Step 1: Implement a standardized and validated intervention program with greater intensity* (e.g., smaller group size, more time). *Step 2: Collect progress monitoring data to determine the effectiveness of the intervention.* Data should be collected using valid and reliable tools and occur on a consistent schedule, ideally weekly. *Data* in this step typically refers to a global indicator, such as curriculum-based measurement (Deno, 1985). Curriculum-based measurement is one type of progress monitoring that typically measures discrete skills, such as computational fluency. While efforts have been made to develop measures that capture more complex constructs (e.g., Project AAIMS, 2007), the current study used the Algebra Readiness Progress Monitoring measures (Ketterlin-Geller et al., 2015) which asked students to compare expressions and select the correct symbol (greater than, less than, or equal). *Step 3: If the student continues to struggle, collect diagnostic information to determine the specific area of need.* This can be done through error analysis of the progress monitoring data, formative classroom assessments, or other precipitating factors like attendance or behavior challenges (Shumaker et al., 2017). *Step 4: Using pre-determined decision rules, make an adaptation to the intervention based on the diagnostic data.* This may include taking a new approach to instruction around specific content, providing additional practice with foundational skills, increasing instructional explicitness, or adjusting the group size or timing of the existing intervention (Shumaker et al., 2017). *Step 5: Continue to collect progress monitoring data to determine if the intervention adaptation is successful and the student is on track to meet the goal set.* Finally, continue Steps 1 through 5 until the student is making expected progress in the content.

School Partners

During the 2018–2019 school year, our university partnered with two schools in the Midwestern United States. Schools were recruited by a researcher from a local university who had previously provided professional development and consultative support to schools and teachers within each district. Southeast Middle School[2] was in a mid-sized suburban school district and consisted of approximately 700 students in Grades 6 through 8. The majority of students identified as white (62%) while others identified as Black (15.2%) or Latinx (7.3%). Center Middle School was in a mid-sized suburban school district. This middle school had approximately 750 students in Grades 7 and 8, with the majority of students identifying as Black (77.4%), followed by white students (13.1%) and then students who identified as two or more races (6.8%).

Teacher Partners

Our team worked with 13 middle school general education mathematics teachers who taught students in Grades 6, 7, and 8. Once school administrators agreed to participate, mathematics department chairs asked for teacher volunteers to participate in the study. Teachers had a range of teaching experience and educational backgrounds (see Table 1 for other relevant demographic information). More than half of the teachers had students with identified disabilities in one or more of their mathematics classes.

Researcher-Coaches

The four primary researcher-coaches were all doctoral-level graduate students in special education and had classroom teaching experience, with some having professional coaching experience (see Table 2 for other relevant demographic information). Three of the four coaches were part of a doctoral training program that specifically focused on special education and mathematics. Each coach worked with the same 2 to 4 teachers throughout the project.

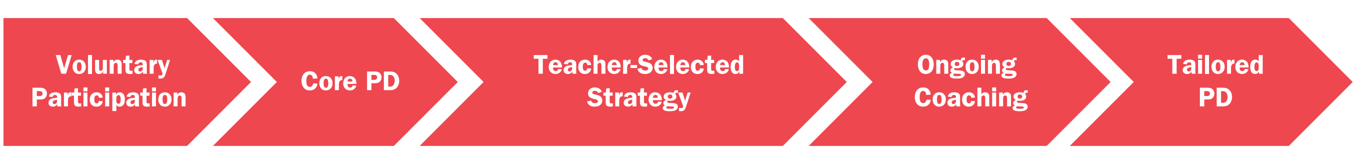
The Project

The interdisciplinary coaching model used in this project consisted of five main steps (see Figure 2).

CORE PROFESSIONAL DEVELOPMENT (PD)

Core Professional Development (PD) consisted of three sessions, each of which lasted approximately 6 hours. The first session described the DBI framework (see Figure 1) and the details of the project. The second session focused on the role of assessment within the project, specifically introducing teachers to the weekly progress monitoring tool. Finally, the third session introduced teachers to evidence-based instructional strategies specifically designed to support students experiencing struggle in mathematics. All three sessions were delivered by members of the research team and were delivered using a strategic combination of lecture, hands-on applied activities, discussion, critical thinking, and reflection.

FIGURE 2. *Interdisciplinary Coaching Model*



[2] All school names are pseudonyms.

Table 1: General Education Mathematics Teacher Demographics

Teacher	School	Years of Teaching Experience	Grade Level Currently Teaching	Highest Degree Earned	Degree Area	Students with Disabilities Enrolled
1	Southeast	16	7	MEd	Curric. & Instruct.	No
2	Southeast	16	7	MEd	Curric. & Instruct.	No
3	Southeast	6	7	EdS	Ed. Leadership	No
4	Southeast	20	8	MS	Counseling	No
5	Southeast	6	8	BS	Math. & Sci. Ed.	No
6	Southeast	19	6	EdS	Ed. Leadership	Yes
7	Southeast	8	6	MA	Teaching	Yes
8	Center	2	8	BA	Mathematics	Yes
9	Center	5	7	BS, BA	Math. Ed.	Yes
10	Center	20	7	MA	Curric. & Instruct.	Yes
11	Center	7	8	BS	Education	Yes
12	Center	19	7	BS	Mathematics	No
13	Center	25	7	MA	Teaching, Admin.	Yes

Table 2: Researcher-Coach Demographics

Coach	Years of Teaching Experience	Teaching Experience	Grade Levels Taught	Years of Coaching Experience	Doctoral Program Math Focus
1	15	SpEd	K–12	6	Yes
2	2	SpEd	pre-K–5	0	No
3	4	SpEd	6–12	2	Yes
4	6	GenEd	K–8	0	Yes

TEACHER-SELECTED STRATEGY

During the third professional development session, teachers chose one of two evidence-based instructional strategies to implement for the remainder of the project: reasoning with multiple representations or teaching with explicitness. Both of these instructional strategies have a solid evidence base in both mathematics education (e.g., National Council of Teachers of Mathematics, 2014) and special education (e.g., Powell & Fuchs, 2015). It should be acknowledged that, because this project was designed and implemented by special education researchers, the manifestation of these instructional practices aligned more closely with special education interpretations.

ONGOING COACHING

Special education researcher-coaches supported teachers in implementing DBI over the course of 7 months. To select students for this project, teachers examined class-wide mathematics screening data and identified 3 to 5 students who were experiencing mathematics difficulty (as indicated by the universal screening measure used by each school) or who had a disability (as indicated by an individualized education plan).

Following professional development sessions, teachers collected weekly progress monitoring data for consented students throughout the duration of the study. Concurrently, researcher-coaches met with teachers in person once per month, during which coaches conducted a classroom observation of the teacher implementing the teacher-selected instructional strategy. Following each observation, the coach and teacher would debrief the observation and plan for additional learning opportunities (Tailored Professional Development). In addition to in-person coaching, coaches and teachers met once per month via videoconference or phone call. These coaching sessions were intended to provide teachers with an opportunity to troubleshoot their implementation of the instructional strategy and plan for the next in-person observation and coaching session.

TAILORED PROFESSIONAL DEVELOPMENT (PD)

In addition to Core PD, each coach tailored their support to the individual teacher with whom they were working. Tailored PD consisted of access to more than 70 brief (3–10 minute) videos that were housed on a researcher-created YouTube channel. Coaches would assess their teacher's need and determine what tailored learning opportunity was appropriate. This support is described as tailored because different teachers across the project had different areas of need related to assessment practices, instructional strategies, and data use.

Data Collection

During the first professional development session and again at the conclusion of the study, teachers took a series of assessments (see Powell et al., 2021, for a complete description), two of which specifically relate to coaching: The Coaching Satisfaction survey and The Teacher Instructional Practices survey.

Measures

The researcher-created Coaching Satisfaction survey was administered to a subset of participating teachers as part of a secondary analysis. Eight teachers from three coaches completed the survey. The Coaching Satisfaction survey measured teachers' satisfaction of coaching using nine Likert scale items (1 = strongly disagree; 4 strongly agree) and two open-response items. Likert scale items addressed the following coaching domains: knowledge of the needs and characteristics of diverse learners, content knowledge, knowledge of research-based practices, responsiveness, the provision of resources, identification of teaching strategies, coach's comfort, coach's professionalism, and an overall rating of the teacher's perception of benefit. The open-response items included the following prompts: "Based on this experience, what would you consider this coach's greatest strengths?" and "Please describe any impacts on your professional practice or other benefits that have resulted from working with this coach."

The Teacher Instructional Practices survey (Powell et al., 2021), which measured teachers' perceptions of the importance of a practice (0 = not very, 4 = very), their understanding of the practice (0 = not very, 4 = very), their confidence in implementing the practice (0 = not very, 4 = very), and frequency with which they currently used the practice (0 = less than once per month, 5 = daily). Survey items consisted of practices related to DBI content knowledge (3 items), instructional practices (16 items), and assessment practices (8 items). The Teacher Instructional Practices survey was administered at the beginning of the first Core PD and at posttest. Internal consistency measures for each section of this survey were well above accepted thresholds (Powell et al., 2021; see Gersten et al., 2005 for accepted thresholds).

Results

Coaching Satisfaction Survey

Overall, teachers *agreed* or *strongly agreed* with all items on the coaching survey (see Table 3 for detailed results). Five of the 8 respondents completed the open-response items. In response to the item "Based on this experience, what would you consider this coach's greatest strengths?", teachers described their coach as "knowledgeable," "helpful," "understanding," "[eager] to help," "supportive," and as having "suggestions on how to incorporate different strategies into [lessons]." In response to the item "Please describe any impacts on your professional practice or other benefits that have resulted from working with this coach.", teachers identified the benefits as "resources," "the graphing tool," and a deliberate focus on "using math specific vocabulary with [struggling] students." Two teachers described relational benefits they received from the experience. One teacher acknowledged the coach's classroom experience as a way to relate to the teacher and a factor that helped the teacher "buy into the research and the opportunities presented

Table 3: Researcher-Coach Demographics

Survey Item	Rating (*n* - 8)	
	M	*SD*
Demonstrated knowledge of the needs and characteristics of diverse learners.	4	0
Demonstrated needed content knowledge.	3.88	0.35
Demonstrated knowledge of research-based practices.	4	0
Was responsive to my needs and concerns.	3.88	0.35
Provided me with useful teaching resources.	3.5	0.53
Helped me identify teaching strategies to better meet the needs of students.	3.63	0.52
Seemed comfortable in their coaching role.	3.75	0.46
Demonstrated professionalism in our interactions.	3.89	0.35
Overall, my ability to meet student needs has increased as a result of my interaction with this coach.	3.75	0.71

Note: Likert scale, 1 = strongly disagree, 4 = strongly agree

for [students]." Another teacher said their coach "opened my eyes to some additional things I could be doing in my classroom to help my students."

Teacher Instructional Practices Survey

When comparing teachers' pre- and post-test mean scores on the Teacher Instructional Practices survey, increases occurred across all Assessment Practice items, with minimal areas of growth in either Data-Based Individualization or Instructional Practices (see Table 4 for detailed results across items).

Discussion

All results should be interpreted with caution given the construct *interdisciplinary coaching* was implicitly measured, but not explicitly named. While the small sample included in these analyses reflect the applied nature of this project, the sample is not representative of the general education mathematics teacher population and should therefore be interpreted in light of school, district, and study contexts.

Findings from the Coaching Satisfaction survey indicate that overall, teachers had high rates of satisfaction with the coaching model used in this project. Answers to the open-response items indicated an additional layer of teachers' satisfaction, naming not only the positive qualities of their coaches but also articulating specific and tangible benefits gained from the coaching experience. These findings suggest promise in using this interdisciplinary coaching model and should be empirically tested to refine the model. Further, the Coaching Satisfaction survey was created by researchers for use in this project and should be further tested for psychometric properties.

The Teacher Instructional Practices survey revealed increased mean scores between pre- and post-test in the domain of Assessment Practices. This was not surprising given the project's intense focus on weekly formative assessment and the use of data to drive instructional decision making. Additionally, gains within this domain reflect the disciplinary expertise of special educators and researchers, including items such as, "Use data from a variety of sources to identify which concepts students are struggling to grasp," "Use screening data to determine which students may be at risk for failure," and "Use progress monitoring data to determine effectiveness of instructional approaches for meeting students' needs." This finding points to one possible benefit of an interdisciplinary partnership that goes beyond discipline-specific knowledge and skills.

Table 4: Teacher Instructional Practices Pre- and Post-Test

Teachers' Instructional Practices		Pre (*n* - 8)		Post (*n* - 13)	
		M	*SD*	*M*	*SD*
Data-Based Individualization	Importance of practice	2.59	0.64	2.28	0.72
	Understanding of the practice	2.26	0.88	2.31	0.66
	Confidence in implementing the practice	2.21	0.83	2.23	0.90
	Frequency of implementing the practice	2.44	1.47	2.46	1.47
Instructional Practices	Importance of practice	2.89	0.37	2.82	0.39
	Understanding of the practice	2.89	0.31	2.87	0.34
	Confidence in implementing the practice	2.87	0.40	2.80	0.40
	Frequency of implementing the practice	4.5	0.71	4.51	0.68
Assessment Practices	Importance of practice	2.44	0.72	2.59	0.75
	Understanding of the practice	2.47	0.64	2.75	0.46
	Confidence in implementing the practice	2.41	0.75	2.77	0.42
	Frequency of implementing the practice	2.38	1.50	2.61	1.50

Note: Likert scale for importance, understanding, confidence, 0 = not very, 4 = very; Likert scale for frequency, 0 = less than once per month, 5 = daily

The minimal or negative ratings in the Data-Based Individualization domain suggest teachers did not gain an understanding or use of this practice. One reason for this finding could have been the diminished use of the term *Data-Based Individualization* beyond Core PD sessions. That is, day-to-day, as teachers and coaches interacted, perhaps the formalized term was not embedded in coaching sessions or other communication. Minimal or negative gains in the Instructional Practices domain could be explained by several factors. First, teachers may have not seen the practices introduced in this study (e.g., reasoning with manipulatives, increasing instructional explicitness) as new and therefore, did not experience increased understanding or use throughout the project. Another reason for this finding could be that teachers focused on different instructional practices and that differences based on the practice they chose were obscured by considering them under the larger umbrella of instructional practices. Future investigations should recruit a larger sample in order to both generalize findings and to allow for additional statistical comparisons between pre- and post-test scores.

Taken together, teachers in this project articulated positive feelings about the coaching experience and, in relation to their assessment practices, demonstrated measurable gains.

Implications for Practice

It is not surprising the general education mathematics teachers and special education researcher-coaches in this study experienced tensions when working towards the common goal of supporting students with mathematics difficulty in the general education setting. In the following section, we share these tensions and describe our attempts to integrate both groups' distinct disciplinary expertise. In addition, we reflect on what we could have done differently in response to these tensions.

Tension: Logistics of Data Collection

The special education researcher-coaches' previous classroom experience was primarily in small group settings in which data collection was a main priority in order to support students with disabilities in reaching their individualized education plan goals. However, in middle school mathematics classrooms of 20 or more students, the teachers in this study felt less able to take time out of whole-group instruction to ensure 3 to 5 students were assessed using the progress monitoring measures. For teachers at Southeast, administering the progress monitoring measure during class time did not make sense. Instead, they believed administration could only happen during a designated school-wide intervention time. This concern reflected the attitude that teachers viewed the DBI process as separate from mathematics instruction and should therefore occur elsewhere. This tension was both an issue of perception and logistics.

REFLECTION: In an effort to support mathematics teachers without discounting the usefulness of progress monitoring in the DBI process, coaches could have framed progress monitoring as another type of formative assessment. Instead of thinking about progress monitoring data collection as something *additional*, the process could have been framed as something *aligned* with what teachers were already doing. In addition, coaches could have planned for ways to streamline progress monitoring efforts, such as supporting teachers in integrating progress monitoring into existing classroom routines (e.g., during a daily warm up).

Tension: Social Implications of Data Collection

A related concern was teachers found it difficult to collect progress monitoring data from a few students and not all students in one class. In a special education classroom, each student is typically working on individual goals and tasks, while in a general education classroom all students are typically engaged in the same activities. In this setting the general education mathematics teachers were reluctant to "single out" students for fear of drawing negative peer attention or having those few students miss out on what the rest of the class was doing. When teachers attempted to address this challenge, their concerns were, in some ways, addressed, yet new tensions arose. At Center Middle, an interventionist administered the progress monitoring measures weekly. While this partial solution alleviated teachers' concerns about integrating progress monitoring into their instructional routine, this arrangement left teachers feeling disconnected from the data and students missing their advisory period. At Southeast Middle, in response to teachers' concern about singling out students, progress monitoring measures were administered during a school-wide intervention time. This approach led to inconsistent data collection, as students often switched intervention class placements.

REFLECTION: While DBI was designed with students who are struggling in mind, all students can benefit from progress monitoring. Coaches could have recommended making progress monitoring a class-wide instructional routine. For students who demonstrated grade-level skills, progress monitoring could aid in goal setting and could encourage ongoing growth. Again, coaches could have engaged teachers around the idea that these types of data were informative about students' learning and therefore, having all students participate in this instructional routine could have minimized logistical difficulties. To avoid students missing out on instruction, coaches could have supported teachers in establishing a regular day and time during which progress monitoring measures could be administered to the whole group.

Tension: Using Assessment Data

The general education mathematics teachers reported collecting both formal and informal assessment data throughout different phases of instruction. When it came to using those data to make instructional decisions, teachers expressed that regular data analysis was not part of their instructional routine, but rather, data were used to justify students' grades. When data were used to drive instruction, they were used to determine whether students learned as expected (and whether it was time to move on to the next instructional unit), but rarely to inform specific instructional moves, like diversifying instructional approaches.

REFLECTION: This tension is not unique to general education teachers, as many teachers experience difficulty regularly and systematically using data to inform instruction (e.g., Schildkamp et al., 2017). Teachers have become proficient at collecting student data, yet one of the biggest challenges teachers face is making the data collection process meaningful by analyzing the data with an instructional lens. Consulting a range of data sources can reveal students' content area learning, but also suggest to what degree a particular instructional strategy either is or is not facilitating that learning.

A practice the study could have incorporated to make this process more meaningful and sustainable for teachers is collaborating with colleagues in order to use data to inform instruction. In future iterations of this process coaches might schedule time with groups of teachers to analyze data and support each other in instructional decision making. In addition to accountability for data analysis, this collaboration could reveal insights about data patterns or instructional adjustments that may be overlooked if analyzed alone. An example from our project involved two teachers who taught different sections of the same course and typically planned together. In thinking ahead to the next instructional unit, graphing on coordinate planes, the teachers considered how students would access this content. Progress monitoring data collected through the project showed that incorporating multiple representations into instruction supported students in learning content in the current unit. Based on those data, the teachers decided to continue using multiple representations and started brainstorming ways this would take shape in the unit. They reported this experience to be beneficial and in the focus group other teachers suggested that more time to collaborate with teachers in the study would be a welcome addition.

Tension: Applying the Instructional Strategy

When thinking about lesson logistics, mathematics general education teachers in our project felt intimidated by the idea of implementing an instructional strategy that was originally designed for students experiencing mathematics difficulty. This perception was likely based on observation of special education classes and traditional intervention approaches. However, the project had intentionally selected instructional strategies that, while effective for students experiencing mathematics difficulty or disabilities, would be beneficial to all students. The mathematics general education teachers were encouraged and supported by their researcher-coaches to utilize the practice during whole-group instruction and not limit the use of the strategy to small groups or individuals.

REFLECTION: To address teachers' concern that they had to create an entirely separate lesson in order to implement an instructional strategy, we encouraged teachers to consider that a robust instructional strategy, like making concepts explicit or reasoning with multiple representations, would support a range of students and could be integrated into existing whole-group instruction. During professional learning, researcher-coaches could have taken a clearer stance about for whom these evidence-based instructional strategies were for. While many instructional adjustments or interventions are designed to support students who are experiencing a particular kind of mathematics difficulty, a range of students can benefit from having access to those adjustments or interventions. For example, using multiple representations has been demonstrated to support students with disabilities in developing procedural and conceptual knowledge (e.g., Strickland, 2017). A teacher might plan to introduce multiple representations with a particular group of students in mind but make the use of those representations available to all students in the class.

Tension: Including Students in the DBI Process

One component the researcher-coaches did not incorporate into the study design was a way for students to be meaningfully included in the DBI process, so that it became something the teacher did *with* students and not *to* students. At the conclusion of the study, teachers speculated about the benefits they thought could have come from including students in the data collection and analysis processes. Teachers thought it could have been meaningful for students and their families to see a student's graphed progress monitoring data and talk about how that was one reflection of student learning. Teachers thought that because curriculum-based measures are especially sensitive to change that students could have had more frequent feedback about their progress (instead of waiting for more formal assessment results) and that this could have demonstrated to families that their student was learning, even if such learning was not detected on other types of assessments. Another unanticipated benefit could have been the use of graphed data to support students in setting goals and feeling motivated by seeing their growth. Within special education, it is common for students to examine their own progress monitoring data. Yet researcher-coaches in this study did not translate that instructional routine to their general education colleagues, wrongfully assuming that such a practice extended beyond the scope of the project.

REFLECTION: One way the study could have planned for and encouraged the inclusion of students in the DBI process would be to turn the collecting and graphing of data into an instructional opportunity. There are myriad ways a teacher could design opportunities for students to learn from graphing, interpreting, and predicting their own (or the class') data. In addition to instructional opportunities, simply asking students to graph and interpret their own data can meaningfully engage them in the DBI process. Most of our teachers used a spreadsheet to track and graph students' progress monitoring data. However, those graphs were primarily monitored by the teachers, leaving students almost completely disconnected from their own progress monitoring. Having students keep their own graphs, on a spreadsheet or even by hand, would be a simple but purposeful way to include students in the DBI process.

Beyond graphing their progress monitoring data, students could be included in decision-making conversations. Teachers could engage students in analyzing their own data for trends. Teachers in our project used Microsoft Excel, which automatically generated a scatterplot and line of best fit. Instead of interpreting the graph themselves, teachers could have analyzed the graph with students. Students could offer insight into scores that seem like outliers, which could give rise to discussion about the influence of a single data point on a line of best fit. After analyzing the graph, teachers could invite students to suggest solutions they think would support them in making progress towards their goal.

The Affordances of Interdisciplinary Coaching

While much of our project involved naming, addressing, and navigating disciplinary tensions, because we committed to understanding and resolving (to some degree) those tensions, there were some over-arching affordances that were born from our experience. In this section, we share the affordances associated with this interdisciplinary partnership.

This year-long partnership necessitated willingness and humility. One of the top-level affordances of this collaboration was the opportunity to work with new colleagues with new ideas, over time. Because this project was centered around the coaching relationship, this fostered a sense of commitment and teamwork. Furthermore, because this project required the teacher-coach dyad to remain intact for the duration of the project, individuals had to persist in working through tensions that arose. Each teacher-coach pair responded to these tensions by forging their own pathways towards better understanding of new concepts, but also a deeper appreciation for the other's disciplinary expertise. Each person's disciplinary expertise and values facilitated work towards the larger shared goal.

One unexpected affordance was the opportunity for general education mathematics teachers to confront the idea that supporting students with disabilities fell within the scope of their instructional responsibility (see Cornoldi et al., 2018 for a description of this tension). While none of the teachers in this study were overtly insistent that supporting these students was not their instructional responsibility, there was evidence that other colleagues, like the special education teacher or interventionist, was considered more responsible. The interdisciplinary nature of this coaching interaction challenged teachers to reconsider how they address the needs of all students in their classroom, even if the range of needs seemed, at times, daunting.

Special education researcher-coaches had to address the genuine concerns of their general education counterparts, which included questions of logistics, as well as the consequences of what it means for students with disabilities to navigate learning in a general education setting with general education peers. Special education teachers often work with students with disabilities in settings in which the only other students are also students with disabilities. However, the general education environment prompted researcher-coaches to weigh the implications of pulling certain students into a small group or asking a small group to do a task that the rest of the class was not asked to do. In this interdisciplinary context, researcher-coaches were pressed to evaluate their standard models of intervention and listen to the perspective of their general education colleagues.

Both teachers and coaches had to bring a certain degree of open mindedness and creativity to the practical problems of implementing DBI in a general education setting. Teachers had to demonstrate a willingness to try new instructional routines and rethink their definition of "instructional support." Coaches had to reconceptualize how instructional supports took shape, looking for opportunities within teachers' existing instructional routines where the instructional strategy might naturally integrate. Since everyone was having to redefine components of instruction and intervention they previously considered static, space was made for posing unconventional solutions or simply trying something and then recalibrating. This interdisciplinary partnership was ripe for instructional experimentation.

Recommendations

Mathematics education leaders are poised to champion interdisciplinary coaching. Based on our experiences, we share some actionable recommendations for taking up this practice.

View Disciplinary Differences as Strengths

Before diving into an interdisciplinary coaching relationship, the coach should see disciplinary differences as strengths. Interdisciplinary coaching requires additional intellectual effort on the part of both the teacher and the coach. Both parties may find themselves feeling misunderstood or like this type of partnership is clunky compared to a traditional disciplinary partnership. Viewing differences as strengths means hearing another's point of view and then challenging ourselves to evaluate and articulate the theoretical foundations of our own ideas, either strengthening or reimagining our views on teaching and learning. Ultimately, this perspective is about valuing the process of engaging in this type of work.

This practice also requires that, in addition to investing in understanding another discipline, we interrogate our own discipline for facets that can be strengthened or changed. We do not intend to suggest that interdisciplinary work is full of dichotomies in which one side is right and the other wrong, where one practice is taken up while another is discarded. Quite to the contrary, we adopt an integrative view in which distinct aspects of each discipline are intentionally interwoven to create a richer and more interesting outcome.

One teacher at Center Middle School was especially committed to supporting all students, including students experiencing difficulty, in mathematical reasoning. This teacher had a deep understanding of the mathematical content and a comfortable grasp of different pedagogical tools. Yet, this teacher expressed a belief that students enrolled in pre-algebra could answer high-level questions, while students in "regular math" were less capable. This belief was translated into practice through the types of questions this teacher posed to students in different classes. The researcher-coach shared this teacher's commitment but saw questioning as a way to increase instructional explicitness and support students with disabilities in reasoning mathematically and developing conceptual understanding. Together, the teacher and coach integrated their expertise and devised questioning sequences that were intended to support all students, but especially those experiencing mathematics difficulty enrolled in the teacher's "regular" mathematics class.

Start Small

A tangible first step to creating an interdisciplinary coaching relationship is to start small. In addition to engaging teachers in more interdisciplinary professional learning opportunities, consider finding one willing teacher who has a different disciplinary background than yourself. With your partner, work together to establish:

- a shared goal;
- depending on the nature of the goal, the duration of the partnership;
- a commitment to meeting regularly; and
- a framework for coaching conversations to ensure everyone's perspective is heard.

In our project, the goal was to support a particular group of students within the general education classroom. While both the teachers and coaches held views about how that goal might best be accomplished, the goal itself was clear. Teachers in our project committed to a seven-month partnership, which resulted in enough time to strengthen the coaching relationship and work together. As mentioned, coaches and teachers met twice monthly (once in person and once virtually). Finally, we used a Coaching Conversation Form (see Appendix A) to add structure to each coaching session. Following each in-person classroom observation, the coach and teacher would complete this form together. After the session, the coach would email the teacher with a recap of the conversation and highlight each person's next steps. At virtual coaching meetings, the coach would refer to the Coaching Conversation Form, follow up on action items, and complete a new Coaching Conversation Form to document the virtual coaching session.

Address Disciplinary Differences

Part of choosing to take on an interdisciplinary coaching relationship is the honest acknowledgement that each person has different disciplinary expertise. We recommend people have these conversations early and often. Start by listing terminology related to your project or goal. Terminology or concepts that might seem obviously universal may in fact have differing disciplinary meanings or unknown nuances. Relatedly, you may both know about and use a particular instructional strategy or move, but call it different things. Making a list of these similarities and differences fosters open and productive communication and understanding. Terminology and concepts are just one example of how disciplinary differences make themselves known. As your partnership progresses, agree to name and discuss disciplinary differences as they arise.

In our project, we often discovered practices or concepts that held relatively similar definitions, but were simply called different things. For most general education mathematics teachers in the study, DBI was a new term, though the process of collecting student data and using it to make some instructional decisions was not new. Relatedly, all teachers in the study were familiar with the idea of using multiple representations to support students' mathematical reasoning, but few considered using those tools specifically to support students with disabilities. During these and other moments throughout the study, our team addressed disciplinary differences in order to understand one another, which allowed us to problem solve and move forward.

Conclusion

Mathematics education instructional leaders are positioned to promote interdisciplinary coaching relationships. The model shared here is one step towards designing instructional supports for teachers that go beyond traditional disciplinary boundaries and seek to expand our practice by drawing from a range of disciplinary knowledge bases and unique expertise. While this experience included tensions and challenges, it also provided an opportunity to maximize disciplinary differences and create richer and more innovative learning experiences, especially for students experiencing mathematics difficulty. ✪

References

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. https://doi.org/ 10.1177/0022487108324554

Brusca-Vega, R., Alexander, J., & Kamin, C. (2014). In support of access and inclusion: Joint professional development for science and special educators. *Global Education Review, 1*(4), 37–52.

Bryant, D. P., Linan-Thompson, S., Ugel, N., Hamff, A., & Hougen, M. (2001). The effects of professional development for middle school general and special education teachers on implementation of reading strategies in inclusive content area classes. Learning Disabilities Quarterly, 24(4), 251–264. https://doi.org/https://doi.org/10.2307/1511114

Bush, R. N. (1984). Effective staff development. *Making our schools more effective; Proceedings of three state conferences.* Far West Laboratory.

Collin, A. (2009). Multidisciplinary, interdisciplinary, and transdisciplinary collaboration: Implications for vocational psychology. *International Journal for Educational and Vocational Guidance, 9*, 101–110. https://doi.org/10.1007/s10775-009-9155-2

Cornoldi, C., Capodieci, A., Colomer Diago, C., Miranda, A., & Shepherd, K. G. (2018). Attitudes of primary school teachers in three Western countries toward learning disabilities. *Journal of Learning Disabilities, 51*(1), 43–54. https://doi.org/10.1177/0022219416678408

Deno, S. L. (1985). Curriculum-based measurement: The emerging alternative. *Exceptional Children, 52*(3), 219–232. https://doi.org/10.1177/001440298505200303

Deno, S., & Mirkin, P. K. (1977). *Data-based program modification: A manual.* Leadership Training Institute for Special Education.

DeSimone, J. R., & Parmar, R. S. (2006). Middle school mathematics teachers' beliefs about inclusion of students with learning disabilities. *Learning Disabilities Research & Practice, 21*(2), 98–110. https://doi.org/10.1111/j.1540-5826.2006.00210.x

Gersten, R., Fuchs, L. S., Compton D., Coyne, M., Greenwood, C., & Innocenti, M. S. (2005). Quality indicators for group experimental and quasi-experimental research in special education. *Exceptional Children, 71*(2), 149–164. https://doi.org/10.1177/001440290507100202

Gersten, R., & Kelly, B., (1992). Coaching secondary special education teachers in implementation of an innovative videodisc mathematics curriculum. *Remedial and Special Education, 13*(4), 40–51. https://doi.org/10.1177/074193259201300411

Individuals with Disabilities Education Act, 20 U.S.C. §§ 1400–1482 (2004).

Ketterlin-Geller, L. R., Gifford, D., & Perry, L. (2015). Measuring middle school students' algebra readiness: Examining validity evidence for experimental measures. *Assessment for Effective Intervention, 41*(1), 28–40. https://doi.org/10.1177/1534508415586545

Knight, J. (2007). *Instructional coaching: A partnership approach to improving instruction.* Corwin Press.

Knight, J., Elford, M., Hock, M., Dunekack, D., Bradley, B., Deshler, D. D., & Knight, D. (2015). Three steps to great coaching: A simple but powerful instructional coaching cycle nets results. *Journal of Staff Development, 36*(1), 11–18.

Kraft, M. A., Blazar, D., & Hogan, D. (2018). The effect of teacher coaching on instruction and achievement: A meta-analysis of the causal evidence. *Review of Educational Research, 88*(4), 547–588. https://doi.org/10.3102/0034654318759268

Lambert, R., & Tan, P. (2017). Conceptualizations of students with and without disabilities as mathematical problem solvers in educational research: A critical review. *Education Sciences, 7*(51), 1–18. https://doi.org/10.3390/educsci7020051

Li, S., Ernst, J. V., & Williams, T. O. (2015). Supporting students with disabilities and limited English proficiency: STEM educator professional development participation and perceived utility. *International Journal of STEM Education, 2*(20), 1–10. https://doi.org/ 10.1186/s40594-015-0033-9

Louie, J., Brodesky, A., Brett, J., Yang, L.-M., and Tan, Y. (2008). *Math education practices for students with disabilities and other struggling learners: Case studies of six schools in two Northeast and Islands Region states* (Issues and Answers Report, REL 2008–No. 053). Department of Education, institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Northeast and Islands.

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM, 51*, 869–884. https://doi.org/10.1007/s11858-019-01100-5

Mackey, M. (2014). Inclusive education in the United States: Middle school general education teachers' approaches to inclusion. *International Journal of Instruction, 7*(2). 5–20.

McLeskey, J., & Waldron, N. L. (2002). Professional development and inclusive schools: Reflections on effective practice. *The Teacher Educator, 37*(3), 159–172. https://doi.org/10.1080/08878730209555291

National Center on Intensive Intervention. (2013). *Data-based individualization: A framework for intensive intervention.* Office of Special Education Programs, U.S. Department of Education.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all.* Author.

Neuberger, J. (2012). Benefits of a teacher and coach collaboration: A case study. *The Journal of Mathematical Behavior, 31*, 290–311. https://doi.org/ doi:10.1016/j.jmathb.2011.12.004

Obara, S. (2010). Mathematics coaching. A new kind of professional development. *Teacher Development, 14*(2), 241–251. https://doi.org/10.1080/13664530.2010.494504

Office of Special Education Programs. (2017). 39th annual report to Congress on the implementation of the Individuals With Disabilities Education Act. Author.

Powell, S. R., & Fuchs, L. S. (2015). Intensive intervention in mathematics. *Learning Disabilities Research & Practice, 30*(4), 182–192. https://doi.org/10.1111/ldrp.12087

Powell, S. R., Lembke, E. S., Ketterlin-Geller, L. R., Petscher, Y., Hwang, J., Bos, S. E, Cox, T., Hirt, S, Mason, E. N., Pruitt-Britton, T., Thomas, E., & Hopkins, S. (2021). Data-based individualization in mathematics to support middle-school teachers and their students with mathematics learning difficulty. Studies in Educational Evaluation. https://doi.org/10.1016/j.stueduc.2020.100897

Project AAIMS. (2007). *Project AAIMS algebra progress monitoring measures [Algebra Basic Skills, Algebra Content Analysis, Translations].* Iowa State University, College of Human Sciences, Department of Curriculum and Instruction, Project AAIMS.

Rexroat-Frazier, N., & Chamberlin, S. (2019). Best practices in co-teaching mathematics with special needs students. *Journal of Research in Special Education Needs, 19*(3), 173–183. https://doi.org/10.1111/1471-3802.12439

Schildkamp, K., Poortman, C., Luyten, H., & Ebbeler, J. (2017). Factors promoting and hindering data-based decision making in schools. *School Effectiveness and School Improvement, 28*(2), 242–258. https://doi.org/10.1080/09243453.2016.1256901

Simonsen, B., Shaw, S. F., Faggella-Luby, M., Sugai, G., Coyne, M. D., Rhein, B., Madaus, J. W., & Alfano, M. (2010). A schoolwide model for service delivery: Redefining special educators as interventionists. *Remedial and Special Education, 31*(1), 17–23. https://doi.org/ 10.1177/0741932508324396

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review, 21*, 365–378. https://doi.org/10.1007/s10648-009-9113-z

Strickland, T. K. (2017). Using the CRA-I strategy to develop conceptual and procedural knowledge of quadratic expressions. *Teaching Exceptional Children,49*(2), 115–125. https://doi.org/10.1177/0040059916673353

van Garderen, D., Scheuermann, A., Jackson, C., & Hampton, D. (2009). Supporting the collaboration of special educators and general educators to teach students who struggle with mathematics: An overview of the research. *Psychology in the Schools, 46*(1), 56–77. https://doi.org/10.1002/pits.20354

van Garderen, D., Hanuscin, D., Lee, E., & Kohn, P. (2012). QUEST: A collaborative professional development model to meet the needs of diverse learners in K-6 science. *Psychology in the Schools, 49*(5), 429–443. https://doi.org/10.1002/pits.21611

Zigmond, N. P., & Kloo, A. (2011). General and special education are (and should be) different. In J. M. Kauffman & D. P. Hallahan (Eds.), *Handbook of special education* (pp. 160–172). Routledge.

Appendix A
Coaching Conversation Form

Teacher & Coach: Use following Action Plan to discuss challenges, concerns, and next steps

Action Plan	
Teacher Perspective	**Coach perspective**
Instruction: Strengths/Challenges	Instruction: Strengths/Challenges
DBI: Strengths/Challenges	DBI: Strengths/Challenges
Potential solutions:	
Teacher's next steps:	Coach's next steps: Recommended resources:
Notes from this session:	
Next meeting: Date: ___/____/ 20__ at ________ Focus of Conversation for Next Meeting: ______________________	

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- *Fostering inquiry into key challenges of mathematics education leadership*
- *Raising awareness about key challenges of mathematics education leadership in order to influence research, programs, policy, and practice.*

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   - Strengthening mathematics education leadership through the dissemination of knowledge related to research issues, trends, programs, policy, and practice in mathematics education;
   - Fostering inquiry into key challenges of mathematics education leadership;
   - Raising awareness about key challenges of mathematics education leadership in order to influence research, programs, policy, and practice; and
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